"Towards an Earth-Moon Economy - Developing Off-Planet Resources"

Moon Miners' Manifesto

& The Moon Society Journal www.MoonMinersManifesto.com

MMM Classics Year 20: MMM's # 191-200 DEC 2005 - NOV 2006

With this issue of the MMM Classics We complete MMM's first twenty years!

As with all previous years, articles covered a kaleidoscope of topics and issues. Following our cues at left, we analyzed **lessons learned at the Mars Analog Research Stations**, and found that they have a strong bearing on how we should, and should not design outposts on Moon and Mars. The concept of **landing a trio of station modules in one place** makes much more sense if we are going to build up the mix of capabilities needed for permanent occupancy. In contrast, the suggestion that each new landing should be at a certain distance from the one before may be an impatient way to explore more territory but by virtue of each such outpost's limited capacity, we risk just setting up a flags & footprints set of ghost towns.

How we'll cook on the Moon is an interesting topic. This time we take up the challenging environmental issues of **barbecuing**.

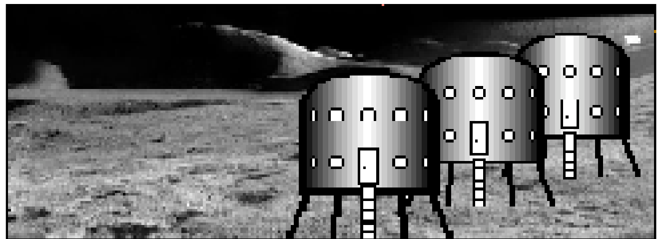
The largest asteroid and the only one to earn the status of a "dwarf planet," Ceres, has become a lot more than another big rock ball. **Ceres** turns out to be a mini-Europa with a significant ocean under an icy crust. Both by size and resources, Ceres seems set to be the gateway not just to the asteroid belt, but also to the entire outer solar system.

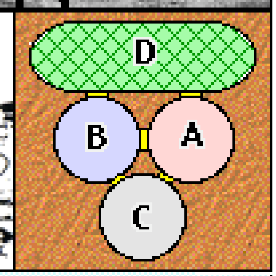
What is the most efficient way to use human labor in setting up and operating a lunar outpost? We need people on site not only to do what robots cannot do, but to **teleoperate** robotic equipment, some of it from up front to minimize the feedback-lag, other tasks from the safer more comfortable Earth, when a 2 plus second time delay is good enough.

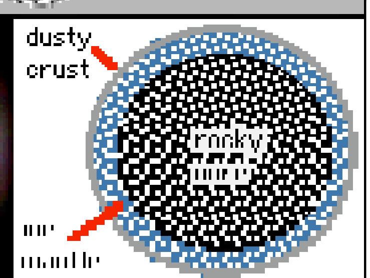
Now most people conceive of lunar outposts and installations as places to which crews come and go. But as permanent presence of temporary crews evolves into a permanent human population, individuals will grow older, **old enough to retire**. Can we find productive, useful work for them? To is it just time for them to go home. We show that a growing senior population could more than justify its role in creation of a true civilian frontier society.

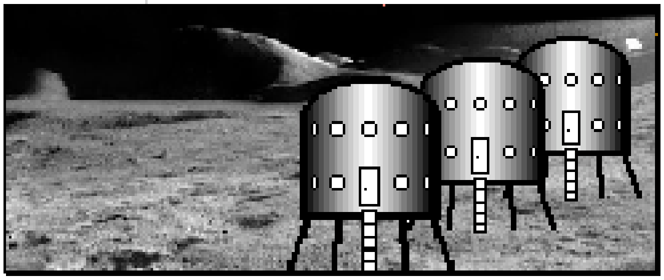
This year as in all the ones previous, we talked about many aspects of how lunar pioneers might come to be truly at home on this challenging new frontier, and about some of the many things that will forge Lunan character and culture, as well as that on Mars.

There are additional articles on how we might use lunar resources, and how we will get around. *Enjoy!*









Robert Zubrin's Concept for a Moon Base

Making the most of the architecture he proposes for an outpost on Mars and its delivery systems, this concept employs a trio of 2-story, 27" wide Habitat modules. The shape is familiar, as the Mars Analogs on Devon Island and in Utah both employ it. We'd prefer a "ranch" design of double-stacked separable single floor units, much easier to cover with protective shielding.

A Moonbase Designed to Work on Mars

By Peter Kokh

It's not about "what" we want! It's about "the best strategy" to get what we want

It is sad to watch the continuing "debate trap" into which many devoted "Moon first" and "Mars first" true believers fall. For in truth, not only would either Moon or Martian settlement prove economically non-viable without each other as a trading partner, both face the very high likelihood of being stillborn, if not summarily aborted, if either one is pursued alone. Politics is the reality, and Collaboration the strategy.

Consider the track record. George W. Bush emasculated the International Space Station by summarily reducing its design manning from seven to three (it takes 2.5 crew man time just to maintain the facility.) Yet he boasts that we have a Space Station.

A Moonbase, designed and pursued as an end in itself, would most likely suffer a similar fate. Reduced manning. No capacity to pursue resource utilization (oxygen production, cast basalt, metal alloys, building materials, etc.) We'd be able to boast that we have a "permanent" outpost on the Moon. Congress would care little, so long as it did not cost any more.

But if the goal is to build a workable Mars Base and try it out on the Moon first, then guess what we'd have?

- **A life support system that went beyond umbilical cord style resupply, rescue, and repai**r, but had to work without relief for extended periods of time, two years or more. This most likely would involve a considerable greenhouse food-growing operation, something that could be easily dropped from a Moonbase-only program, given inevitable budget pressures.
- **A design that had to take "shieldability" into account** because the long stay times on Mars demanded such protection. On the Moon, in contrast, you could do without shielding if you rotated crews frequently enough.
- **A robust machine shop and repair facility**, because on Mars, one might have to fabricate a critical part if the last spare had been used.
- **Development of an adequate power system** *not reliant on "eternal sunshine"* which is something that would not be available on Mars. We might end up with a power system that would let us operate anywhere on the Moon, not just in the polar cul de sacs of *"eternal sunshine."*
- **Inclusion of a superior medical facility** that with aid of the latest computer software programs from Earth would allow treatment of almost any medial emergency. In a Moonbase-only operation, we'd have emergency transport back to Earth as a crutch to fall back on.
- **Quicker development of expansion architectures that relied as much as possible on locally produced building materials, modules, and parts.** In a Moonbase-only operation, we'd continue to rely on shipment of made-on-Earth modules (hard hull, inflatable, or hybrid) and parts.
- **The living spaces would be more likely to include the perks and amenities needed to ensure sustained crew morale and productivity over yearlong plus stays.** In a Moonbase-only operation, we'd make do with submarine style living standards, or less. Such perks are an essential step towards the introduction of optional re-upping, signing up for continued stay duty - one small step on the road to the first "settler."

I am sure there are still more points to make!

The one thing that wannabe Lunans and wannabe Martians both don't seem to get, is that while Mars offers an atmosphere rich in oxygen, carbon, and nitrogen, plus a hydrosphere of unknown size, a more day-like rotation cycle, and other amenities, *it remains initially a much harder nut to crack,* because it lacks the one thing that the Moon offers: "location, location, location."

Ironically, however, that "location benefit" *can and will serve as a crutch* that will be used by bean counters and politicians to restrict full development of any "government" (national or multinational) outpost to the bare minimum to allow boasting that "we have one."

I write this article as a solitary individual, as editor of Moon Miners' Manifesto, not as President of Moon Society,many of whose members, and perhaps directors will be hard to move off previous turf-protective positions. But I counsel them to consider that it is in our best interests as advocates of lunar outposts, and local resource-using settlements that on this point of posture towards the Bush Exploration Initiative, it is very much in our own best interests to ally ourselves with the well-articulated position of the Mars Society and standing side by side with them, work in unison for a Moonbase Designed for Mars.

It's not suicide. It's not a paradox. It's simply far and away the only strategy that makes sense. Now I suspect that younger readers and members (not old enough to have vividly remembered our retreat from the Moon at 8:42 p.m. EST on December 16, 1972) will disagree. But if you don't remember history, you are doomed to repeat it!

Let's not be fools. To one who lived through the Apollo era, the naiveté of many younger enthusiasts is both incredulous and discouraging. We must take the longer view, and that means playing our strategies to the hilt. **<PK>**

ALUMINUM WINDOWS

Safer Windows for Spacecraft & Surface Vehicles? A Solution for Some Lunar Architectural Challenges?

[sources: Google.com: ALONtm]

By Peter Kokh

Well, windows of a new *ceramic* aluminum oxynitride rather than aluminum alloy, actually. Trade named ALONtm [no, that's not ALON™] this new material is being tested at Army Research Laboratory at Aberdeen Proving Grounds, Md., and University of Dayton Research Institute, Ohio adjacent to Wright-Patterson Air Force Base. The driver here is to come up with a superior transparent window for hummers and other vehicles at high risk in Iraq. But the implications for safer vehicles and structures in space are what interests us.

ALONtm research to date

ALONtm is a ceramic material with high strength under compression, superior impact resistance, and superior abrasion resistance. It is lighter weight than traditional multilayered glass windows with which armored vehicles are now being outfitted.

Lighter, thinner, stronger, longer lasting - is there a downside to this new miracle material? Cost is currently a problem. $10-15 per square inch as compared to $3 for multilayered glass now in use. But that should not be of concern to anyone familiar with the downward cost curve of any newly introduced product. As more efficient ways are found to process the material, and mass production is introduced, costs should fall substantially. After all, and this is something few of our readers under 70 will be aware of, when the commercial products made of the new miracle alloy "aluminum" first appeared, they were *astronomically* expen-sive. Aluminum is now very affordable, no longer in the Platinum cost range. In fact, it is now a "common" material.

Drivers for development of ALONtm

The need for protection from road side bombs in Iraq, and from terrorist threats in general, is driving this research. That the R&D is being done by the military means that all the money needed to be thrown at it, will be.

We can feel confident that this technology will be available commercially without too much delay. Armored vehicles used to transport millions of dollars in gold bullion or paper currency between banks, are logical early users. Once the cost becomes competitive, if not lower than armored multilayer glass, more commercial applications will appear. Wherever wealth or political clout makes someone a target, there will be a premium on "the best protection."

But we see a big market for ALONtm windows and portholes on the space frontier.

ALONtm windows on tourist craft and orbital hotels

Sometimes, the enemy is none other than ourselves. This is certainly the case with the growing problem of space debris in low Earth orbit, almost all of it avoidable for the cost of a few added measures and procedures. [See MMM ##31 DEC '89, "Space Debris: cleanup & prevention" p1 - included in MMM Classics Vol. 4 available as a free PDF download from www.lunar-reclamation.org/mmm_classics/] Larger, safer ALONtm windows in tourist spacecraft and tourist hotel complexes in orbit will be demanded by both would-be tourists and the insurance industry. The cost of minimizing risks will be more than made up by the overall fall in ticket prices by a greater volume of tourist traffic driven by the realization of higher safety levels, less risk.

Yes, it is true that the likelihood of an impact from a debris particle of size sufficient to cause vehicle or structure decompression is low, it is getting ever less so. It is clear that the public regards the 1 in 50 chance of loosing a shuttle too high, and the first such debris-impact decompression fatality will have a very chilling effect on the infant space tourism industry. Commercial vendors and fliers of tourist vehicles will be happy to pay any extra cost that reassures potential customers. A century ago, had we the technology to go into space without the current culture of risk-aversion, no one would have hesitated. But these days, the public believes everyone should be guaranteed to live to a "ripe old age." That's nonsense, of course, but that is the depth of cowardice to which we have now fallen. It is going to be difficult to populate a frontier given this culture.

The risk of a debris or micrometeorite decompression accident beyond low Earth orbit falls substantially, but once it is common practice to equip space vehicles and living spaces with ALONtm panes, they will become standard. Even where there is a low incidence of risk, the cost and great inconvenience of changing a window out in the open, as opposed to inside a pressurized "garage" would make the higher protection worth additional cost. Apart from greatly improved failure protection, the fact that ALONtm is significantly more abrasion resistant will make vehicles so equipped very attractive, especially on Mars where wind-driven dust is expected to be a real problem. ALONtm windows remain clear, glass gets sandblasted to a state of translucency without transparency.

ALONtm windows for habitats and other structures on the Moon and Mars

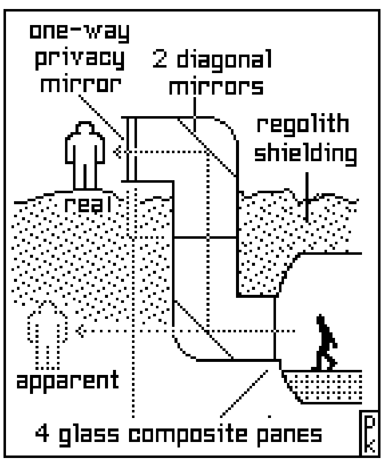
We personally, have always believed that television screens and monitors are no substitute for actual vision when it comes to keeping in touch with the outside world. Electronic devises can always be fed a misleading signal, and they just do not convey the same sense of immediacy. Our interest in such devices as periscopic picture windows had a lot to do with the birth of Moon Miners' Manifesto in the first place: our belief that "Lunans may have to live underground, but they won't have to live like moles. They can bring the views and the sunshine down underground with them." [Cf. MMM #1, December '86, now online, fully-illustrated: http://www.lunar-reclamation.org/mmm_1.htm]

Many articles have appeared since then in MMM in which the use of windows was central. Here are but a few:

#74 APR '94, p 6. Visual Access; p. 7. Sun Moods
75 MAY '94, p 4. Lunar Appropriate Modular Architecture
#124 APR. '99, p 4. Windows Focused on Earth
#132 FEB. '00, p 8. Skylight Domes for Lavatube Towns

Also see:
www.lunar-reclamation.org/papers/habitatmoonmars_1.htm

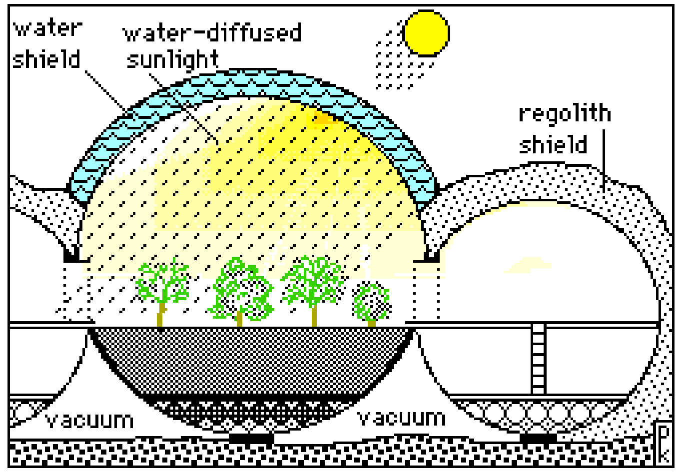
Realizing that exposed glass would lose its transparency over time due to micrometeorite and dust abrasion, we postulated a loose "sacrificial" pane in front of the window, that could easily be replaced. But the superior qualities of ALONtm would make such replacement much less frequent. Even if ALONtm was used just as a replaceable weather shield, its value would be significant.



For periscopic windows which would have several panes stepping down the pressure differential between inside and the out-vac, it might be prudent enough to tmake only the outer pane of ALONtm, doubling the protec-tion offered by an ALONtm sacrificial pane.

If costs every plunged to the point where ALONtm panes could compete with ordinary glass, then they could be used for the convex facets of a lunar geodesic dome type skylight. Convex or inward curving panes would take advantage of the fact that ALONtm is stronger in compression. However, any direct path visual or solar access, unless seldom used by any one person, would provide severely insufficient shielding against cosmic radiation and solar flares. That's why the periscopic window makes use of a zigzag pathway.

Why not store water overhead where, within a double layered glass dome, as translucent shielding? This is a suggestion of Marshall Savage (Millennium Foundation).



You will notice that while from the outside, it looks like a dome, the true nature of this structure is a sphere which better handles the pressure loads. Now this is a neat idea, but the water would have to be circulated to prevent freezing or boiling (in lunar versions). Thermal management will be a major part of any such design, and a lot of homework and trial and error prototype demonstrations need to be done here on Earth with sun/heat/cold loadings that simulate the proposed environment (Moon or Mars). And now that both the domes "glass" layers could be made of ALONtm instead of glass, makes this suggestion somewhat more practical, *provided that* the plumbing systems to manage the thermal swings can be perfected.

Can we have translucent shielding without water? Glass, if it is thick enough, or in enough layers to provide shielding (6-13 feet!) loses its transparency and even its translucency. It would be interesting to see how much light is lost per mm or cm of ALONtm as compared with the same thickness of glass. If ALONtm is a sufficiently more efficient transmitter of light, it might make some new architectural options possible.

Recently, a form of concrete has been reduced that is translucent, not transparent (you can see someone's silhouette but not make out the details). Read about it at: http://optics.org/articles/news/10/3/10/1

> "Thousands of optical glass fibers form a matrix and run parallel to each other between the two main surfaces of every block," says inventor Áron Losonczi. "Shadows on the lighter side will appear with sharp outlines on the darker one. Even the colors remain the same.

All these new wonder materials will in time open up exciting new options for lunar, and Martian architecture, just as they are sure to do sooner, here on Earth. In ALONtm, we have what could be a wonder material whose further development and application will be abundantly funded by both military and civilian consumer interests. The offshoot will be a safer, and perhaps more pleasant life for those who pioneer worlds beyond Earth's life-supporting biosphere. Windows, skylights, solar access for homestead gardens and greenhouses, revolving restaurant observation towers over Luna City or Marsport. Ceramic aluminum, made of everyday elements, has a role to play.

A lesson that younger readers can take away from all this is that all the excitement is not in propulsion science. A career on the new frontiers of Materials Science can help as much or more open the space frontier. The Rocket guys can get us there. It will take the Materials Science guys, the chemical engineers, the experimental agriculture people and others to help us find a way to stay on that frontier, and to make it just as much our own as has been the planet of our birth. Plus, there's money to be made advancing materials science right her and now. **<MMM>**

COLOR THE MOON For our prior article on this subject, MMM # 63 March '93, p 10. Color the Moon "anything but gray" see MMM Classics Vol. #7 a free download pdf file from:
http://www.moonsociety.org/publications/mmm_classics/

Color the Moon

"anything but gray?"

By Peter Kokh

The Moonscapes are studies in gray tones from near black to near white. Exceptions are rare. When Apollo astronauts stumbled on a small patch of regolith with a faint orange tint to it, there was a great deal of excitement on two worlds.

Living in such an environment while maintaining morale will require doing something about this situation of sensory deprivation. We have the capacity to see colors, and as in other matters, appetite follows capacity. Colorizing the lunar environment, both in indoor and out-vac settings, will take some careful forethought and prior experimentation. There follows a short quote from the previous article cited.

> The principal avenues for introducing color on the Moon as in Space Settlements built mostly of lunar materials are these: **1)** luxuriant green vegetation and colored foliage and flowers; **2)** naturally colored cotton and natural organic fabric dyes that do not stress water recycling systems; **3)** vitreous stains for coloring glass and glazing ceramics; **4)** inorganic "paints" that do not tie up precious carbon or nitrogen; finally **5)** colored "neon" lighting using noble gases scavenged from regolith-moving activities.

In this article, we'd like to talk about bringing color to the Lunar outdoors. Now that may sound a bit ambitious! We do not mean to colorize whole moonscapes, only the external faces of settlement structures: the shielding mounds, the airlock "porches," etc. things that personalize one family's homestead from another's when viewed from out-vac, from out on the surface.

• See MMM #55 May 1992, p 7. MOON ROOFS. This article has been republished in MMM Classics #6, available as a free download pdf file from
http://www.lunar-reclamation.org/mmm_classics/

Early Colorizing Agents

Perhaps the first colorizing agent to appear will be **rust-ochre** from harvested pure iron fines that are allowed to oxidize in a humid environment. This will happen quite naturally inside lunar homesteads if regolith is brought inside along with large rocks to create a Japanese style sand garden. The regolith will have to be sifted to remove the troublesome fine powder portion, but any of the iron fines remaining, or any large particles to which iron fines adhere. will inevitably rust. This will be a welcome "splash" (if you dare call it that) of color.

Out-vac, a regolith shielding mound could be lightly "dusted" with rusted iron fines to customize it. As this would be but a thin coating, in a windless environment, a little will go a long way.

Probably next will be **white**. Lime, calcium oxide, can be produced from highland regolith which is very rich in calcium. But perhaps the first source of white dust available to those who want to put their digs in the "limelight" will be titanium dioxide, a byproduct of producing iron and oxygen from ilmenite, $FeTiO_3$, Iron Titanium Oxide.

Ilmentie is not found everywhere. Regolith rich in this ore are very dark, the Taurus-Littrow valley Apollo 17 site being an example. But it offers one of the easiest routes for both oxygen and iron extraction, with titanium dioxide as a byproduct. Oddly, the very same people who propose beginning lunar industry with ilmenite want us to go to the polar "eternal light" [PEL] sites, and the two are nowhere collocated. But assuming NASA and the planetary scientist bandwagon comes to its senses and does not choose a polar dead end site, ilmenite-derived white TiO may be available early on.

Now many of the virtually unlimited colors we are used to enjoying will not be sourceabe on the Moon because they incorporate one or more elements found on the Moon only in trace proportions: copper, lead, cadmium, etc. But feasible possibilities include:

- **Pale Yellow:** Sulfur, as a pale yellow powder, alone, or mixed with titanium dioxide, it could give a faintly creamy look to surfaces dusted with it.
- **Red:** aluminum oxide mixed 4:1 with ferric oxide Fe_2O_3. A spinel, $FeO.Fe_2O_3$, produces a darker red. A tomato red can be prepared from Uranium oxide which can likely be found with known Thorium deposits
- **Red-brown:** (in addition to rusted iron) might include the reddish brown of iron chromate $FeO.Cr_2O_3$, the Indian red-brown of magnesium-iron oxide $MgO.Fe_2O_3$, and the red-brown manganese titanate $MnTiO_4$
- **Pink:** the least expensive approximation of pink will be a mixture of iron oxide rust with white lime or titanium dioxide. Feasible alternatives are a manganese-alumina

pink and a chromium-alumina pinkish red. Cobalt-magnesium combinations might produce a pink to lilac range .

- **Yellow:** in addition to the pale yellow of sulfur, the only feasible options would seem to be vanadium-zirconium and titanium-iron oxide preparation
- **Orange:** the cheapest route is adding iron rust to sulfur powder, *slowly.*
- **Green:** The deep emerald green of chromium oxide may be the standby. This could be blended with available yellows and blues to produce neighboring tints. Chromium oxide can also be pasteled by adding titanium dioxide. Later on, and more expensive to prepare, a blend of yellowing vanadium and bluing zircon in the presence of sodium fluoride (if fluorine can be produced, a difficult but high industrial priority) is an option. Praseodymium (from KREEP deposits) phosphate with a calcium fluoride additive is another.
- **Blues:** Cobalt aluminate yields the most beautiful matte blue*, and cobalt silicates and oxides produce mazarine blue, royal blue, flow blue, and willow blue. A titania-alumina blue, $TiO_2.Al_2O_3$, with a corundum structure is a possibility but hard to prepare by synthesis as opposed to starting with Ti-rich bauxite. Alternatives include a vanadium-zirconia blue and a silica-zirconia-vanadia-sodium fluoride system of blues, turquoises and greens.

* *at a local chemical supply house, I paid $128 for a few ounces of cobaltous aluminate ten years ago. So blue will not be cheap. However it can be mixed with lime or titanium dioxide to produce lighter pastel tints , or with manganese dioxide or ferrous oxide black to produce grayed blues for a proportionately diluted bottom line.*

Back to our Out-vac Applications

To colorize anything out-vac, (out on the vacuum washed surface) by dusting stabilized surfaces with colored powder will not be cheap both because of the expense of preparing some of these powders, and because of the amount needed to make an effect on large surfaces. We can predict that except for iron oxide rust, titanium dioxide white, calcium oxide white, and sulfur yellow, all of the above mentioned compounds will be too expensive to apply liberally. In that case, except for those to whom money is no object, *we are talking about subtle colorations, tinted grays, not expanses of pure colors.* The less you can afford to shell out, the more subtle the color shading of the basic regolith. That said, one could fairly cheaply specify lighter highland regolith, and against that background, less colorizing powder will go further.

Grayed Colors as particularly appropriate

For the visitor or traveler, to come upon a patch of surface that was colored in some pure, ungrayed fashion, would probably be offensive and grotesque. Gray regolith tinted with colorants, however, would seem to pay due homage and respect to the host terrain. Regolith mounds so shaded would stand out, but not garishly. They would set the tone of synthesizing human tastes with the host palette.

Lime white, and iron rust will be the two options inexpensive enough to be used liberally so as to minimize graying by the regolith on which which they are dusted.

Now there will be gaudier displays of color out-vac, but in the form of road-signs etc. where there is a need to have the item in question stand proud from the surface so as to be recognized and understood. But our point is that we can subtly colorize the external manifests of human occupation on the Moon while still paying all due respect and blending in. We wonted be substituting pure colors for gray. We will be subtly colorizing the grays. This economics-reinforced practice will serve to wave our basic human pride, and at the same time proclaim to all that we are proud to be Lunans. Grayed colors will be part of Lunan culture. **<MMM>**

The First Lunar Manufacturing Industries

or, Before we Start Building HABITAT MODULES

By Peter Kokh

Before we can start manufacturing items needed on the growing lunar outpost settlement-to-be, we have to start producing manufacturing materials: metal alloys, glass and glass composites, etc. But this article is not about that. In two previous articles, we looked at manufacturing items in general out of sintered iron fines (using powdered metal technology) [MMM #63 March 1993 p 5. Sintered Iron from powder] and out of Cast Basalt using solar concentrators [MMM #35 MAY 2000. p 7. Cast Basalt: Industry Perfect for a Startup Outpost] Here we want to look at what our overall manufacturing diversification strategy should be.

ASSUMPTIONS: [1] When it comes time to expand our starter outpost, we can't just start building habitat shells without also producing the items needed to outfit them: utility systems, interior partitions including floors and ceilings. [2] To start manufacturing both habitat shells and innards is too big a bite all at once.

PROPOSAL: [3 Why not have the first interim hard hull expansion modules manufactured on, and shipped from Earth built to the same desired cross-section dimensions of our planned made-on-Luna Habitat modules and with the same interior and exterior interfaces? Then we can start manufacturing the sundry outfitting items. When we are ready, we can take on the manufacturing of additional modules on the Moon. [4] The empty made-on-Terra Hab shells can be filled, for transit, with equip-ment needed for other purposes on the Moon.

Relevant Articles from MMM back issues

MMM #18 September 1988, pp 3-4, "'MUS/cle' Strategy for Lunar Industrial Diversification." Online at: www.lunar-reclamation.org/papers/muscle_paper.htm

MMM #74 April 1994; p. 8. "KGB" Drop-in Cores (KGB: Kitchen, Garden, Bath)

MMM #75 May 1994
- p 4. Lunar-Appropriate Modular Architecture

MMM #76 June 1994,
- p 4. Inside Mare Manor; Interior Walls
- p 5. Wall Surfaces & Trimwork
- p 8. On the Wall: How to hang stuff;
- p 9. Ceilings, Flooring

The "MUS/cle" strategy

Lunar industry should concentrate on the **M**assive and/or **U**nitary (we need a lot of such units) and/or **S**imple items that will make the biggest dent in the gross tonnage that must be imported from Earth and to let terrestrial suppliers continue to produce the more **c**omplex and/or **l**ightweight and/or **e**lectronic components that in aggregate comprise a lesser gross tonnage to be imported. The earliest lunar manufactures will be things that do not have to be made of refined advanced materials, which are not complex in assembly, and of which we need a lot of, if not in numbers, then in total gross tonnage. Both habitat modules and many of the outfitting items needed to make them occupiable will fit into this category.

Bypassing the dilemma

Now this may seem another instance of the "which came first, the Chicken or the Egg?" dilemma. But I suspect, just as with the age-old question above, the choice is moot if there is no "Rooster" involved. In our case, the question is which to manufacture first: outfitting or habitat shells? The dilemma is solved by the "rooster measure" of having all pressurized modules imported for outpost expansion shipped unoutfited, basically empty except for things the infant lunar industry cannot yet handle, e.g. the utility runs and electrical harnesses, and so on. The modules of which *the original outpost core* is built will have come ready to use, of course. But now it is time to expand beyond that core.

The cheapest way to import more habitable space will be with inflatable structures and/or empty and not-yet-outfitted hard hull units. The time for this momentous switch will come when lunar industry has begun producing metal alloys, cast basalt, glass fibers, glass and cement. Made-on-Luna habitat modules could be made of metal alloy, fiberglass reinforced concrete or (fiber)glass-glass(matrix) composites. But meanwhile, these same materials can be turned into modular sections for interior wall partitions, flooring and ceiling systems, tables and other furnishing items which do not need to be made of sophisticated modern materials.

"Size matters"

To make this strategy work, a decision must be made very early on about various interfaces, critical dimensions, etc. What we manufacture on the Moon to outfit empty inflatables and hard hull modules from Earth should ideally be designed to fit the kind of modular architecture and units we will want to build on the Moon. The most critical decision would seem to be radius or cylindrical cross-section. As it will be much more efficient to build two story units, it would be better to use the ET's 27 ft. girth as a guide, than the 15 ft inner diameter of the Shuttle Payload Bay. New launchers may give us more freedom but we should not count on a Heavy Lifter being developed, no matter how much sense it makes. There is an old maxim about "infrastructure lasting forever." In very old cities, usually the only thing that survives the ravages of time are the road right of ways. So if we know where we want to end up. perhaps we should design our launchers accordingly. Their capacity enables everything.

Substitution shipments

If for the shipping stages, the shape and size of the cargo alone matters, and weight is less of an issue, other items needed on the Moon, including manufacturing equipment, tools, and small, lightweight "cle" components ca be shipped inside the empty habitat hulls in place of the weight that the various outfitting items to be added on the Moon would have totaled. The bottom line is the same. Less shipments and less total tonnage leaves Earth for the Moon. The infant outpost-settlement-wannabe makes up the difference and perhaps then some.

The "Stowaway Import" Option

Let's say that the infant lunar industry is not yet quite ready to produce some of the outfitting items, but is ready on most. An elegant choice if to ship the Earthmade module with the items that cannot be made yet on the Moon, but manufacture those items out of materials sorely needed on the Moon but in which the Moon is deficient. Copper, lead, zinc (or bronze, brass, pewter); silver, gold, even thermoplastics that can be melted down and recast into items difficult to make from metals, glass, ceramics etc. Such outfitting items can be replaced by made-on-Luna equivalents made of cruder lunar materials, when lunar industry is up to it. At that time, the replaced items can be cannibalized for their rare and precious elements. In effect, copper and the other elements in question get "stowaway" passage to the Moon. [See MMM #65 May 1993, p7. "Stowaway Imports"]

Outfitting for All Modules, or just Some?

Before we begin to develop interfaces and standards for a modular lunar architecture that is versatile enough to meet most needs, we will want to have spent some quality time designing a modular lunar-appropriate architectural "language." In this language, the interfaces are the grammar, the various types of modules are the nouns and verbs. In our article in MMM #75 on Modular Lunar Architecture we postulated that a successful Lunar-appropriate system would be one that incorporates these Six Elements:

1. the smallest number of distinct elements
2. the greatest layout design versatility
3. the most diverse interior decorating options
4. fabricated with the least labor and equipment
5. assembled with the least EVA and equipment
6. pressurizable after the least total crew hours

Now it is conceivable that Lunar industry will be ready to outfit some kinds of modules, say dormitory units residence units, or agricultural pods, before it is ready to produce drop-in kitchen-bath units, for example. In this case, we make the most appropriate choice between shipping some modules fully outfitted, others empty, still others with temporary replaceable and cannibalizable items. The point is that the transition from shipment of fully outfitted units to shipment of wholly unoutfitted ones need not be an all or none decision. We can phase this in, easing the transition, building up confidence and experience in the new lunar industrial teams.

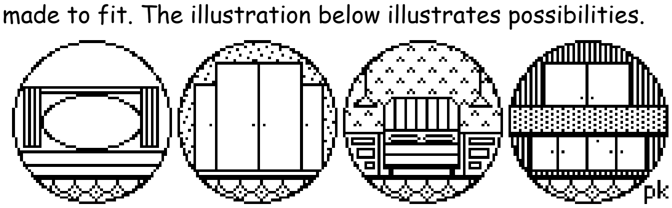
What outfitting items will be manufactured first?

We go back to the MUS/cle strategy for guidance. What outfitting items, easy enough for lunar industry to tackle now, will, multiplying individual item weight by the numbers needed, make the biggest dent in the import burden? Interior wall, flooring, and ceiling systems perhaps. If these are modular, combinations that fit inflatable interiors should produce no extra manufacturing burden. Planter trays for the agricultural units, for sure.

If we can come up with a modular way of making a number of case goods items (cabinets, tables, dressers, desks, etc.) then the various components of those. What about utility components? Pipes and conduit would get the nod over switches and valves, even over elbows and tees. You get the idea. The MUS/cle strategy makes decisions and diversification strategizing a fairly straightforward process in which consensus replaces power plays by those seeking personal economic advantage.

Special Assemblies

As manufacturing volume and diversification both increase, the market for special assemblies will grow to the point of making it worthwhile to produce them. For example, the round hemispheric end of a habitat module Teed off of a residence modular complex, provides a specially shaped concave area right for mass-production of alternative units made to fit. The illustration below illustrates possibilities.



L-R: periscopic picture window unit, closet system, bed headboard wall, countertop with upper & lower cabinets.

The point is to get started. Here is a path from outpost expansion to settlement building in earnest, that is just-on-time, versatile, and which makes economic sense. For most writers, getting from the starter outpost to the first settlement is a mysterious transition to be taken for granted. MMM is all about life on the early frontier, not about the first foothold outpost. "Getting There" for us is not the rockets that emplace the starter outpost, but rather the staged rocket of infant lunar industry that will get us to the early lunar frontier populated by pioneers who have left Earth behind, ready to make this new world their new home. **<MMM>**

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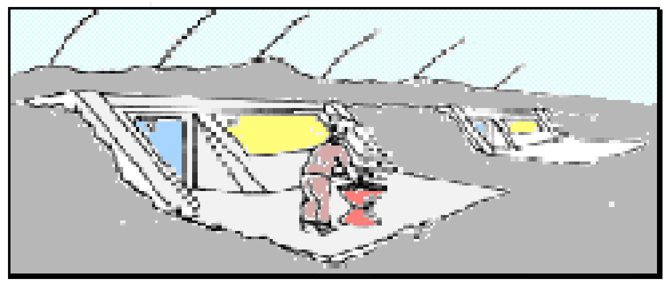


Will Lunar Pioneers every enjoy a Grilled Steak?

Certainly in the early period of Lunar Settlement, a protein-enriched vegetarian cuisine will be the easiest to realize. Meat production, as now practiced, "hogs" precious resources. Cooking methods that fill the air with odors, aerosol greases and particulates will be frowned on, if not against the law. Settlers will survive these strictures. In "The Embers," *below*, we explore the possibilities.

Coloring the Moon: Three More Options

By Geoffrey A. Landis

Editor's Forward

We welcome this substantial contribution to the topic of introducing colors into our Lunar frontier outposts and settlements. In MMM #191, Dec. '05, we had updated our previous article "Color the Moon anything but gray" which appeared in MMM # 63 March '93, p 10 - included in MMM Classics Vol. #7. We had also touched on the subject in an article about how pioneers would learn to love the Nightspan in MMM #43, March '91, p. 4 "Nightspan" -now included in MMM Classics #5.

There will be many ways to introduce color in addition to oxide tints processed from the regolith: colored bulbs including neon tubing, clear water-filled bottles with drops of vegetable food dyes, stained glass, organic dyes for fabrics; and plenty of vegetation including multi-colored foliage and flowers. A carefully selected ecosystem for interlinked public spaces may include some songbirds, butterflies, and other animals. Aquaria with brightly colored fish will be popular.

Geoffrey Landis adds three chemical pathways to introducing inorganic colors that we had not thought of.

Colors on the Moon don't have to be mineral pigments based on iron, titanium, and aluminum oxides plus sulfur. Here are three additional sources of colors from lunar materials:

Color Centers

First, we can make colors by the use of color centers in glass. Think of rubies and emeralds. They are brilliant red and green, but the material itself, beryl, is almost colorless. The color comes from color centers (often known as "F-Centers", from the German), which are defects that interact strongly with light, created by doping with a small amount of a foreign element. Color centers don't need to be created only in precious stones, however, and it is easy enough to make colored glass using tiny amounts of a dopant to color a much larger amount of glass. Glass is likely to be one of the first things we make on the Moon, and colored glass could be an early product. Grind up colored glass, and you will make a pigment out of it; glue the colored glass to a surface, perhaps using a lower-melt-temperature glass as the binder, and you will be able to enamel or glaze a surface in many colors. Or, perhaps stained glass might end up being the decorative craft best suited for the Moon. One problem with color-centers in glass, is that they tend to bleach or blacken with exposure to ultraviolet. So,if you want a color that stays bright even after years of exposure, colored glazes and stained glass are likely to be a source of color for the inside of the habitat only.

Iridescence*

A second source of color that is a natural for the Moon is thin-film iridescence-- the "soap bubble" effect. A film of a transparent oxide can be made so thin that it reflects only a single color of light. Perhaps you've seen jewelry made by forming thin films of tantalum oxide on metals? That's iridesence. This forms the color for most butterly wings, as an example. As it turns out, this tech nology is incredibly easy on the Moon-- aluminum, silicon, and titanium are three of the most commonly available oxides on the Moon, all three oxides are quite transparent, and all of them can and have been used to make quarter- and half-wavelength films. And the method for making high-reflectance half-wave films are simply vacuum deposition-- a technology that couldn't be better adapted for the Moon, where vacuum is free. Almost any metal object could easily be colored in all the shades of the rainbow. The films will be hard (although, if you're coating aluminum, scratching the object will scratch through the film into the metal; there's no protection if the metal itelf is soft.) And, since the thickness of the films is so low (typically below a micrometer), they don't radiation darken very quickly-- an iridescent metal coating will stay colored for a long, long time.

[*from the Latin word for rainbow. Thus *Sinus Iridium* (Bay of Rainbows) in northern *Mare Imbrium* (Sea of Rains)

Nanoparticles

The third source of color to consider is nanoparticles. I'm not talking "real" nanotechnology here; it's not even really high technology. Small particles, with sizes ranging from a few tens of nanometers up to a micrometer or so, can interact very strongly with light, producing colors. To make a paint, you would have to manufacture these nanoparticles and then disperse them into a binder. In its most elementary form, nanoparticles of gold have been used from antiquity as a method of coloring stained glass (the mechanism is different from the F-center mechanism discussed above, by the way), and nanoparticles are being studied for a wide variety of other applications, of which paint is not the least. So it is very likely that, by the time we're looking for coloring agents, nanoparticle fabrication is likely to be available. **<GAL>**

Geoffrey A. Landis
NASA Glenn Research Center
Ronald E. McNair-NASA Visiting Professor of Astronautics at MIT
http://mit.edu/aeroastro/www/people/landis/landis.html

Landis is a member of the Moon Society Board of Advisors. He is also a published science-fiction author of note. *The editor highly recommends* his novel "**Mars Crossing**" Tor Science Fiction (2001) ISBN: 0812576489

The EMBERS

The Settlement's first Controls-Exempt Open-flame BBQ-Grill Restaurant

By Peter Kokh

Sacrifice on the Lunar Frontier

Many of the things we enjoy in the modern world conditions in which we live, those who choose to join the lunar pioneer settlements will be consciously agreeing to kiss goodbye. One of those may be a charbroiled steak or a side of barbecued ribs. Meat eaters especially will have to make a considerable adjustment, and, as recruits, will probably be required to live in a settler candidate camp for few months. One of the reasons for this will be to see how well each of them can handle the heavily, if not exclusively, vegetarian diet. Those who miss meat too much may become disgruntled settlers, and should be discouraged from continuing.

The question of meat protein]

There are, of course, purely vegetarian sources of proteins: nuts and legumes, and especially soy products. At the Mars Desert Research Station, February 26-March 11, [2006] our Moon Society crew will get first hand experience of how well, or how poorly they satisfy a meat-lover's cravings. But in Laurel Ladd, we have an experienced vegetarian Chef! The crew will be invited to give thumbs up or thumbs down on each of her crockpot creations, approved menus and recipes going into our Lunar Frontier Cookbook. The crew does include a majority of meat-eaters, however. So this will be interesting. Modeling an Early Space Frontier (assuming a greenhouse in place for three months) is a mission project.

In time, but probably not anytime soon, the settlement will grow large enough to dedicate space and resources to raising the most efficient meat-producing animals: fish, cavies (guinea pigs), rabbits, and chicken, in that order, I believe. One teasing possibility, now still science-fiction, is that we might learn how to culture select meant tissues (chicken breast white meat, for example) in nutirent-laden vats. Not only would that be a vastly more efficient way of producing meat protein, it would be "meat without the face." That meat comes from living animals is a problem for many.

Food Preparation Constraints

But there are also constraints, once/if/when we do have a small meat or meat tissue supply, on how it is cooked. In our recent article, "Cooking on the Moon," MMM #189, OCT. 2005, pp. 7-8, we noted that cooking methods which released too much vapor into the air would pose a problem for ventilation and air refreshening and recycling systems in the small volume settlement with no great outdoors or world wide atmosphere to dilute odors and replace indoor air with outdoor "(relatively) fresh air." Boiling and frying (especially the latter) would not be long tolerated.

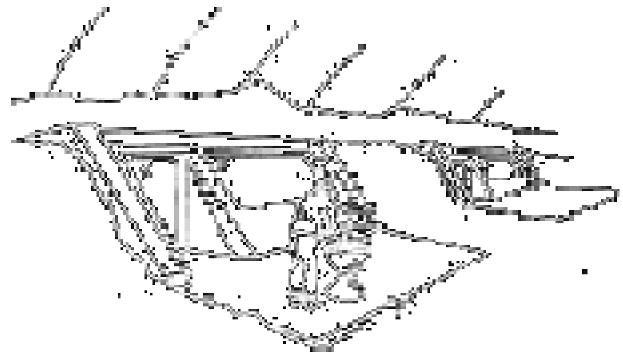
The problem with charcoal grilling

But grilling and barbecuing, backyard style or even indoor tabletop Hibachi style would present the added problem of smoke, the very thing that gives us the flavor we want, as meat grease drips on the coals and back-splatters the grilling meat. Our porches, and we will have them, will open onto pressurized streets with a very limited capacity to absorb the vapors in comparison with Earth's vast atmos-phere. Neighbors might like the odor for a bit, then resent being so teased.

From MMM #33 - March '90, PRINZTON: Part VII: Conclusion. A. Prinzton in a Multi-Site Lunar Economy. Reprinted in MMM Classics #4 p. 18

RESORT COMPLEXES: More easily realized and sooner needed would be a resort complex offering safety-valve and escape features to make life on the Moon a little less harsh. Starting with the assumption that as individuals will spend only small fractions of their lifetimes in such a facility, we suggest that much less shielding mass be used. A much stronger single vault to hold the atmosphere with greatly reduced compensating overburden weight would be an attractive possibility if that overlayer were in translucent form. "Cracked" color-free or bluish glass above an air-tight sky-pane:? Layerof therma expansion? Decisions for R&D.

Such a vault would offer a blue dayspan sky without heliostats. Along with "country" cottages set into the rille slopes and having added shielding on their individual roofs, the shield mass above the vault could be kept to the minimum necessary to allow the desired degree of translucency. For not only would vacationers spend only a week or two a year in such a spot, call it "Lost Valley." they would spend perhaps a third or more of that time within the further-shielded cottages.



Vacationer barbecuing on cottage patio

Illustration © 1989 David Cramer - The 1989 LRS Prinzton Study. Republised in MMM Classics # 3 and 4; paper online at: http://www.lunar-reclamation.org/papers/rille_paper1.htm

Under what conditions might grilling be allowed? Will there at least be restaurants where one can go to get a decent char-grilled steak, even if one isn't allowed to cook this way in his own homestead? Perhaps not right away, but eventually? I suspect the answer will be "yes." by long-pent-up popular demand. And that is what this article is about.

Fast Forward: The Settlement's 10th Anniversary

January 1, 2025. The young settlement of Luna City now growing rapidly at the "North Junction" site along the northern coast of Mare Frigoris where a new road had been built northwards some 243 miles to a middling size crater near enough to the Moon's north pole to have a sizable permashade area, with confirmed water-ice impregnated regolith of minable concentrations. The settler's traced the city's foundation date right back to the landing of the first module of the commercial outpost, a full two years before NASA began erecting its south polar base, now long since abandoned. For in truth, the commercial outpost began expanding immediately, at first with Bigelow Aerospace inflatable modules but after the first two years, with modules made locally of glass composites and other building materials produced on the Moon.

The culture of protein-enriched vegetarian cuisines worked well with the greenhouse-based biosphere system, a modular one which grew as a system apace with the physical complex. Meanwhile, on Earth "vat meats" now vastly improved over the "textured mush" first produced in 2009, was winning many converts as more and more people had good results grilling "real" chicken, pork, and beef "faux" fillets, chops, and steaks - all boneless, of course.

Now Angus McAllister, developer of the Heaven's Gate resort complex just south and west of the lower entrance to the Alpine Valley (the main transportation corridor between Mare Frigoris and Mare Imbrium "and points West, South, and East" had applied to the Lunar Frontier Territory's Department of Global Expansion for a variance. Angus wanted his resort to feature a good old fashioned Steak House and BBQ grill. Not only would this satisfy the needs of meat-eating tourists from Earth, but it would serve as a real getaway attraction for settlers, rewarding them for their long patient toleration of the basic Lunan diet.

Somewhat of a Culture War skirmish ensued. But vat meats were already making a modest inroad in Luna City grocery sales, and it was more of a question over perceived threats to air quality and other quibbles. Well aware of the unreconciled political pressures, the Department issued a trial license for one year, with some strictures. This restaurant was to be a test prototype and no more "BBQ Grill licenses" would be granted until an environ-mental impact review was completed following the first year in business of "The Embers."

If the review showed that the various environment-protecting measures had been unquestionably successful, a permanent license would be granted. If the review showed mix results, a one year extension of the temporary license would be granted, after all recommended corrective measures had been taken. The owner had the right to appeal those conditions on grounds of economic impracticality, but a successful suit would be pretext for shutting the place down. There was strong incentive for both parties to cooperate, but without compromise.

McAllister agreed. His establishment would not be connected to the rest of the resort complex, but stand alone at some protective distance within a half hour's ride in a motor coach. (For customer's the ride only whetted their appetites that much more. Free cocktails were served on the coach, of course!) The restaurant would have to have its own air and water recycling systems and an approved way to deal with solid meat wastes, greases and fats,. These systems would be much more elaborate and costly per volume serviced than those in Luna City or Heaven's Gate.

For McAllister, the obvious downside was that these constraints tripled his projected costs, and these would have to be passed on to customers just like all other costs-of-doing-business. The restaurant would have to charge proportionately steeper prices. On the other hand, Angus would be serving not just ordinary weekday or week-end customers, but people on luxury vacations, people for whom splurging for a good cause (and one's taste buds qualified) was not a problem> To the contrary, returning home to brag about having "the greatest steak of my life at the Embers" was worth the cost. After all, why do people watch their pennies day in, day out, week in, week out, if not to have something with which to splurge in earned release?

From one to many

This test enterprise was an unqualified success. The Embers was popular with tourists and vacationers, of course, but also attracted a fair share of the birthday-anni-versary-wedding-retirement party business. Party rooms to cater to these customers were included in a first expansion. A second expansion housed a dinner theater complex.

Per permit, any fresh uncooked meat scraps were turned into sausages under the Embers™ brand, sold all over the Moon at a high premium. The Embers could not only grill and broil, but fry and boil, and more than a few customers ordered menu items prepared in these ways also.

The Embers was the first of what are now known as first-class licenses. Similar establishments have appeared at the Luna City spaceport, and at other tourist clusters as well as some of the more roadside inns. But stand alone first class restaurants remained the exception. Most such license holders were hotels, resorts, and inns offering overnight accommodations.

Life on the Moon slowly began to be a little less "frontier-harsh" and a little more "terrestrial." But the pioneers still had their share of special cultural features about which to brag, or complain, as individual temperament dictated. The moonfolk were becoming "citified!" **<MMM>**

WEATHER FORECASTING ON THE MOON

By Peter Kokh

Talk about the weather!

The very idea of a weather bureau issuing fore-casts for Lunar pioneers at first blush seems absurd. "No atmosphere, no weather," it's a no brainer! Either the Sun is out and you can't see the stars in the black sky for all the glare, or it's Nightspan and stargazing still is not that good when Earth, 60 times brighter than the Moon is for us phase-for-phase, makes stargazing less than rewarding also. Unless you are on Farside during local Nightspan, where the Milky Way is so awesomely brilliant it wants to suck you up into its bosom! Talk about star travel!

But seriously, no thunderstorms, no lightning, no hail, no tornados, no hurricanes, cyclones or typhoons - no tropical storms period, no blasts of Arctic cold: nothing but the boringly predictable cycling of Nightspan and Dayspan, of superficial heat and superficial cold.

All so true! On the other hand, the Moon is subject to Cosmic Weather events that for Earth, our atmosphere serves as a resilient shield. Cosmic Rays get through, of course, but on the Earth's surface, Solar Flares and mete-orite storms are scarcely felt, though we can observe their rites of passage through the atmosphere: the auroras and the Meteor Showers - neither of which will be visible phenomena on the Moon.

Both Solar Flares and some of the denser Meteorite swarms will make the morning and evening news on frontier radio,television, and internet stations. For Solar Flare events, travel restrictions will apply. No one should be further than an hours drive from the nearest flare shelter. But perhaps there will be meteorite shower alerts only for spacesuit pedestrians out on the surface without the protection that even a covered rover can provide.

Sounds pretty boring. They better come up with a panoply of sporting events or else no one will have anything to talk about other than political scandals, and who got pregnant by whom. Weather for us, even when it is rather nice, is a great ice-cutter for starting up a conversation. Pioneers fresh from Earth will miss it. "Hey, what about this weather?" will become a popular inside joke.

We have nonetheless found enough to talk about concerning Moon Weather to feed two past articles:
MMM #5, May '87 "Weather" - find it in MMM Classics #1
MMM #148 Sept. '01, p. 7 "Music of the Lunar Spheres"
www.moonsociety.org/membeers/mmm/mmm148_Sep2001.pdf

Twin eternal dust storms, circling the Moon forever

Three decades of data from an instrument left behind by the Apollo 17 crew, intended to track dust from meteorite instruments, have instead revealed an unexpected phenomenon. The instrument, called LEAM for Lunar Ejecta And Meteorites, has been gathering data since 1972. As the rising Sun sweeps the surface that has been in darkness for almost 15 days, an electrostatic effect levitates some of the loose fine particles. Looking at the Moon along the sunrise terminator, imagine one long linear storm or suspended dust stretches from pole to pole, a distance of almost 3,400 miles. As the terminator advances, the storm follows, but like the phenomenon of a wave traveling through water, new particles rise at the front replacing others that settle at the rear. The storm follows the sunrise terminator around and around and around, circling every 29.5306 days. It has been going on, apparently, for billions of years.

All the Apollo landings occurred, complete with takeoff, during midmorning lighting conditions. NASA wished to avoid the long shadows of dawn, the high heat of midday, and the cold of night. No astronaut has experience this storm. We have a lot to learn about it. How dense are the particles? How much do they obscure vision? How much of a problem will they pose for astronauts, explorers, and settlers? Will the levitated dust insinuate itself into space suit joints, will it clog up vehicle lubricants? Will it abrade windshield glass? We don't know and we need to know.

NASA intends to send crews to a polar site, where, if there is a similar opposite effect along the sunset terminator, the two storms will link up playing crack-the-whip. Or they may peter out closer to the poles. We don't know.

A commercial base, constrained by economic sense and the resource needs of diversified industrial development would hardly choose a polar cul-de-sac site only to developmentally handicap itself. So commercial astronauts are likely to experience this wispy sinuous dust storm rolls every morning, once a sunth (lunar month = 29.5306 days). But we are not even sure that they will see it without special equipment. The swirls of dust may be so wispy as to be invisible to the naked eye, at least to the untrained eye.

It seems we need to send a new instrument package designed to answer our questions. Right now all we have is some tentative theories. Timothy Stubbs of the Solar System Exploration Division at NASA's Goddard Space Flight Center suggests the explanation may be that "the dayside of the moon is positively charged; the nightside is negatively charged. At the interface between night and day, electrostatically charged dust would be pushed across the terminator sideways, by horizontal electric fields.'

But we don't really know. It's not just a matter of scientific curiosity. We need to know if it poses a problem for equipment and for personnel out on the surface. If it does, we need to figure out how to work around it. We will be at home on the Moon, only when all its dangers become so well known that we act appropriately as it by second nature. That day will come! **<MMM>**

Source:
http://science.nasa.gov/headlines/y2005/07dec_moonstorms.htm

SPIN UP TECH UPDATE

By Peter Kokh

Washing Clothes and other fabrics on the Moon presents a challenge to closed water recycling systems. Detergents would have to be *quickly* biodegradable, and the remaining lint and soil must be filtered out of all graywater.

Fresh water not water already "gray" from sinks and showers, must be used. The amount of water in the clothes washing loop must be added to the amount needed for drinking, food preparation, hygiene, food production, household cleaning chores, and last, but not least in closed-loop industrial processes.

But what if you could wash clothes with air? No water would mean not only less demand on the limited settlement "hydrosphere" but less fabric degradation through linting! No water also means no drying, thus less consumption of energy. And if keeping the settlement cool, not warm, is the problem, as we expect, then not having to dry clothes with heat would be a big plus. Of course, there is always the old-fashioned way: hanging them out to dry. But either drying process adds to the humidity in the air, which we expect to be enough of a problem without help from clothes drying cycles.

While washing with air would have clear benefits for settlement environments, it would also be a boon for many places on Earth where clean water is quite scarce.

There may be such a way say two enterprising scientists in Singapore. Read the article online at:
http://www.heraldsun.news.com.au/common/story_page/0,5478,17965878%255E11869,00.html

Substitutions Key to waterless washing

What seems to be involved is a pair of substations that few would have been clever enough to try:.

swirling water >>>>>>> ***jets of air***
detergents >>>>>>> ***negative ios***

The negative ions work to clump dirt and dust together, deactivating bacteria and neutralizing odors. ***Electrolux*** is one company that has looked at the prototype with interest. Developing a needed-in-space technology for terrestrial profits is what we call "Spin-*up*" **<MMM>**

[SPIN-UP TECHNOLOGY CHALLENGE]

Troublesome Moondust May have an Achilles Heel

It Smells!

By Peter Kokh

Source:
www.redorbit.com/news/space/375271/the_mysterious_smell_of_moondust/index.html?source=r_space

Previous articles in MMM
MMM #89, Oct. '95, pp. 6-7 "Dust Control"

"It smells like burnt gunpowder,"remarked Gene Cernan. Apparently, every astronaut who made it the Moon's surface smelled it. Most felt it - "it's soft like snow, yet strangely abrasive (Cernan). Some tasted it -- "not that bad," (Young). Yet as they all soon learned, it gets everywhere, in every nook and cranny. It gave Jack Schmitt the first brief case of "lunar hay fever." Scientists are worried about Moondust playing havoc with equipment and machinery, getting into the tightest joints, wrecking ball bearings, junking up grease and lubricants. They worry to about it's long term effects on astronaut and pioneer longs. Will it be something like silicosis? of coal miners' black lung?

All of us who want to see the lunar frontier develop into another settled world, are optimistic without reason to be that this potential problem can be managed, that we can learn to live with moondust as we have with many irritants here on Earth. Hope and temperament-based confidence will not "make it so." We have to do several things:

- Use architecture and engineering to minimize amounts of moondust that infiltrate our habitation and work spaces.
- "Turtle-back space suits that remain outside while the occupant climbs out the clamshell back docked with a conformally shaped airlock. Throwaway paper coveralls might help but would have to be carefully designed and any tear or rip would compromise their effectiveness.
- Car-wash airlocks are another option, one drastically more expensive and complicated.

Perhaps robot-insects small enough to get in most nooks and crannies and able to climb walls and ceilings, and with the capacity to sniff out even traces of moondust will serve as an early warning system of problem areas and suggest remedial design and engineering changes.

If some terrestrial entrepreneur developed such tiny, go anywhere sniff detectives, there should be ample Earth-bound needs for such devices to earn a fortune. And meanwhile, a technology we need on the Moon, would be ready for us, "on the shelf," thanks to "spin-up." **<MMM>**

Hmm? If the dust at the Mars Desert Research Station has a characteristic smell, a prototype sniffing device of this sort could "test" our Hab-tightening remedies!

Microwave Oven Technology for Road Building on the Moon and for much, much more!

By Peter Kokh based on a report online at:
http://science.nasa.gov/headlines/y2005/09nov_lawnmower.htm?friend

A matter of perspective

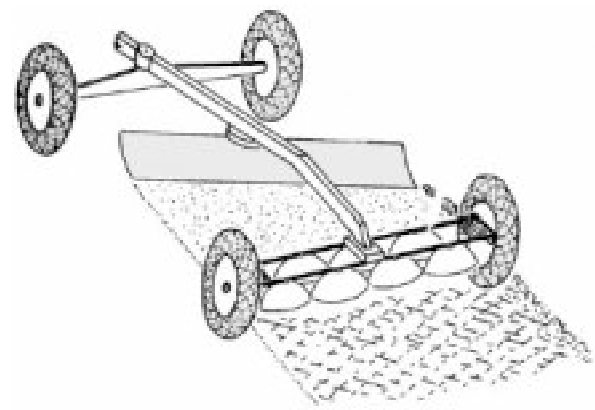
Sometimes, quite often in fact, the problem is its own solution. It's a matter of looking at it right. "If something seems like a disadvantage or a liability, you aren't looking at it from the right angle!," is a bit of wisdom from my Mother that I have found to be the key to paydirt many a time. Moondust is insidious. It gets into everything, and it is everywhere on the Moon, the product of four plus billion years of micrometeorite bombardment.

Larry Taylor, Professor of Planetary Sciences at the University of Tennessee, as he has a habit of doing with everything (including a bar of Irish Spring soap), put some moondust from NASA in his microwave oven, and within seconds, even at low power setting, it fused into a glob.

You see, one of the omnipresent ingredients of moondust is microscopic particles of iron. We all know well enough not to put metal in a microwave! The iron in the moondust absorbed the microwaves, heated up, and fused all the moondust! Eureka! The brainstorming began!

What can you do with microwave-fused moondust?

Well suppose you put your microwave magnetrons on a wheeled carriage and drove it (in person, or more likely, telerobotically) over the terrain?



Cartoon sketch by Larry Taylor, U. Tennessee

"With the right power and microwave frequency, an astronaut could drive along, sintering the soil as he goes, making continuous brick down half a meter deep--and then change the power settings to melt the top inch or two to make a glass road." Taylor calls this the lunar lawnmower, though that implies an operation that has to be done often.

Send us your suggestion for a more appropriate metaphor? email us at kokhmmm@aol.com

Taylor suggests that bricks could be made this way and that we could even fuse the inner slopes and floors of appropriately sized craters into reflective bowls that would serve as Arecibo like radio telescopes.

A family of applications - (suggestions by this writer)

A device like this could **"fix" the "apron"** surfaces around docking ports and airlocks, lessening the chances that moondust would get carried into the pressurized areas. That's really "job one" in road building. To paraphrase an historic quote, "all lunar roads begin and end at an airlock."

One can imagine **a hand held unit** that one would wave briefly over one's space suit, especially arms, gloves, legs and boots, fusing the dust into clumps that would shake off, and do no harm even if carried inside. But the settings would have to be low enough to cause no accumulative damage to the human inside. We all know that microwave ovens won't work with the door open, and there is a very good reason for that!

Inside, a takeoff on the hand held unit above would be magnetron-equipped **vacuum cleaners attachments**. The fused dust would be more easily and thoroughly sucked up.

Such a process might have architectural applications as well. Consider the lunar settlement's surface appearance as a collection of inter-linked molehill mounds - the regolith shielding piled on top of habitation structures being the public face of the settlement from outside. An affluent person could have his "mound" fused, and maybe in some pattern forged as the mobile fuser's route could be chosen for such special effects. As the microwaves can reach some distance down, a mold of some neutral iron-free material could be placed and tamped on the mound section by section and the soil fused beneath it. The mobile unit would then raise the mold, wheel to the next area, tamp the mold down, fuse, etc.

Mold fusing could become an inexpensive way to produce many products for both domestic and commercial use, for both lunar and off-Moon markets - where performance was not a critical issue. How brittle would such artifacts be? How susceptible to cracks? How susceptible to corrosion and decay by exposure to water, or even to humid interior atmosphere? We don't know the answers to those questions. How much experimentation can be done here on Earth (with lunar simulant?) and how much corroborating experimentation will have to be done on the Moon? All we can do is carry terrestrial experiments as far as we can.

Can you see a terrestrial application of such technology? Why not develop the technology for profits here and now, while putting a needed lunar technology "on the shelf," the research paid for by terrestrial consumers?

An invitation to brainstorm

What other possible applications are there? "The only limit is imagination," says Taylor. More importantly, the answer is really up to those of us who can take it to the next step. Might that mean you? **<MMM>**

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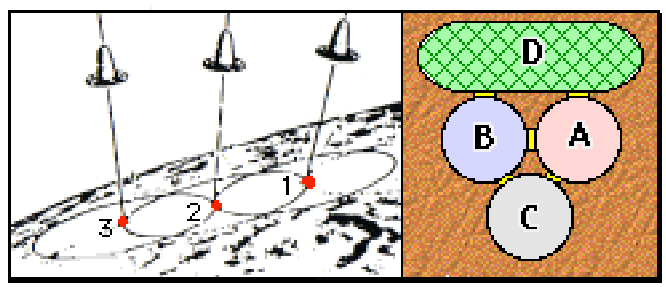

Send (3) Habs to (1) Site on Mars, not to (3) Sites!
[Left] The plan of Mars Direct would send successive manned missions to separate sites: good for exploration, bad for establishment of a viable outpost. Experience at the Mars Analog Stations shows convincingly that all the facilities needed for viability over many months cannot be crammed into one Hab structure. [Right] A) Residence, B) Laboratories, C) machine shop/fabrication, D) Greenhouse. See *below.*

IM FOCUS Where we're at & where we need to go in Mars Exploration

By Peter Kokh

The International Robotic Exploration of Mars has been in full swing now for several years. Every successive launch window, 25+ months apart, sees a number of new orbiters and/or lander/rovers sent out by NASA and ESA. The Japanese and Russians plan to get in/back in the fun.

While the twin rovers, *Spirit & Opportunity* are still hanging in there, sending back many thousands of fascinating pictures, their science is very, very local. The

European *Mars Express,* and its bevy of instruments, however, have been revolutionizing how we see Mars. Mars was once wet, a *looong* time ago, and still retains some water ice reserves. Some of these may be near the surface, shielded from sublimation by a thin layer of dust. Other reserves have been detected at some depth.

What has not been detected is the widespread presence of underground aquifers such as we find on Earth.

The implications of this are that we will have to be quite choosy where we decide to set down, so that accessing subsurface water-ice is not an improbable challenge. The mars Express instrument readings also seem to rule out present day sources of geothermal power. This is disappointing but hardly a surprise.

The great Martian volcanoes seem to have been quiet now for billions of years. Get used to it: geothermal power won't be among our energy options.

A fleet of Mars Prospectors

There is much more to learn about Mars before we can rationally plan a manned landing mission, especially to a location where we intend to dig in for an indefinite stay:

- **Orbiter Probe to detect Subsurface Voids**: Conditions for the formation of Karst limestone caves do not seem to have ever existed on Mars. However, we would be stupefied if the vast Tharsis Uplift and great Martian shield volcanoes were not laced with lavatubes that could provide voluminous shelter for settlements, industrial parks, and warehousing.
- **Lander driller(s)** to determine thermal flow subsurface temperature gradients)
- **Chemical Prospector Orbiter** to look for *all the elements needed to support an industrial civilization:* Fe,Al,Ma,Ti,Na,K,P,Lb,Cu,Pl,Th, etc.
- **Data Mining Challenge for Earth based team:** *define the drainage basins* from existing MOLA data; highlight future rivers and lakes in a terraformed Mars, as well as
- **Phobos-Deimos Prospector Mission** to analyze the chemical makeup of the surface regolith and any exposed bedrock on Phobos and Deimos. This is absolutely necessary if we are to determine the roles these two moonlets can play in bolstering the now weak Economic Case for Mars (realistic Export products that can competitively earn income for the settlements.)
- **Establish an Artificial Intelligence-run forward teleoperations base on Phobos and/or Deimos** to allow teleexploration of Global Mars in near real-time, without the ridiculous 6-40 minute time delays experienced in teleoperation of *Spirit & Opportunity* from Earth.

Evidently, we have quite a lot to do to prepare for an aggressive manned Mars Mission program. And it seems clear that with missions currently decided by Planetary Scientists who may be disinterested in a Manned Mars Program, that we will not get the type of orbiter and landing probes we need without aggressive agitation, going over the heads of the "specialists," if need be. Privately funded Mars Missions under the Planetary Society, may be our big hope.

The Planetary Society is at the top, when it comes to designing probes, or instruments to be added to them, that excite the public attention: e.g. the Mars Sundial, and the Mars Microphone. But NASA's abandoned *"Kittyhawk"* project to fly a drone plane over Valles Marineris should be revived as well. There is obviously room for *organized* activist input! In the strange absence of Mars Society initiative here, the Planetary Society may be our best hope.

The upshot is that while NASA/ESA are generally moving in the right direction, corrective inputs are much needed.

One can ask who is trying to do the same for the Moon. True activists launched the effort that Alan Binder would bring to conclusion: a probe that would find indications of water ice particles concentrated at the poles. That was the "and behind door #1*" (of the common perception that the Moon is no more than a rubble pile.) A similar effort that we might call "and behind door #2", an effort to get launched a probe that could detect any subsurface voids such as lavatubes that would serve as safe harbor from the scouring cosmic weather has failed. Perhaps such an instru-ment first flown over Mars could be reflown over the Moon.

[* MMM # 133, Nov. 1999, In Focus Editorial, pp 1-3] – **PK**

From the Arctic & Desert Analog Stations to a Real 1st Human Outpost on Mars

Changing Mars Mission Plans to fit the many lessons learned on Devon Island and in Utah

by Peter Kokh, MDRS Veteran, Crews 34 & 45

The Mars Direct Mission Plan Revolution

Mars Direct, the Mars Mission Architectural revolution introduced by Dr. Robert Zubrin more some fifteen years ago, showed how we could mount exploratory missions to Mars with far less throw weight, total tonnage to be paid for dearly with fuel, than NASA's then conventional mission architecture forecast as necessary. By the simple device of making the fuel for the return on Mars itself, instead of carrying it along, as well as all the fuel needed to get that return fuel to Mars, the cost of human missions to Mars was cut to a tenth. Now exploring Mars became something we could budget for, something in 1960's dollars, not much more than another Apollo Program.

But another Apollo Program, a heroic Flags & Footprints Epic to be followed by yet *another half century of nothing*, is not exactly what we need. By the plan, if the first unmanned crew return ship lands successfully and produces fuel successfully, then, at the next launch window

25 plus months later, a manned Habitat would be landed at the same site, along with a second unmanned crew return ship with fuel making capacity to a site reachable by the first party if necessary. Then another manned Hab would be sent to that second site, etc. Over a period of 8 years, three manned Habitats would be established on Mars, each to be abandoned when its crew went home.

First things first! Settling in before Exploration!

While this plan introduces measures to guarantee a safe return of each crew, and to gradually extend the reach of manned exploration across the globe, it clearly puts exploration ahead of establishment of even one viable outpost. In fact, none of the three manned Habitats would be viable for more than weeks, in our opinion. They are each too small to house all that is needed to sustain a crew for up to two years in good physical *and mental* health. I say that having spent two 2-week tours (one month) of duty at the Mars Desert Research Station in Utah.

Before I make that particular case, let me advocate clearly and forcefully that *exploration should follow, not precede establishment of a permanent outpost*. We know far more about North and South America and Australia through exploration *by their own settlers,* than we could ever have learned from a series of expeditions leaving from and returning to Europe. Why? *Logistics, logistics, logistics.!*

Exploration is best done from up close, by people living off the land, because it is their land. *We must not let the curiosity itches of planetary scientists be scratched at the expense of settlement.* In the long run, settlers will find out vastly more about Mars than "foreign" explorers bent on leaving the land they are exploring.

The Mars Analog Habitats tell the tale.

The Mars Hab testbeds at the Flashline Mars Arctic Research Station on Devon Island and at the Mars Desert research Station in south central Utah, are classical cases of design according to the principal "function follows form." Yes, I know that's backwards. That's precisely the point. Instead of defining the facilities and functions we need in a self-sufficient crew habitat, and then finding a modular architecture to house those functions, we have settled on a fixed volume structure, determined not by the needs of usage but by the needs of transportation to the site. Then we have sought to cram all the needed facilities and functions into that fixed volume.

And guess what? *They don't fit.*

That's not apparent to many crew members because they are there for a 2 or 4 week tour of duty. But Mars crews, on the real (not analog) Mars will make that Hab home for two years or more. If FMARS and MDRS veterans are honest, they will realize that neither Hab can produce its own food, produce its own energy, or keep itself in good repair *without all too frequent outside inputs, help, rescue, and resupply* - recourses that could not apply on Mars itself.

There is no real allowance for crew recreation - on two week tours, you can simply go without. There is no real attempt to rely solely on original rations and food grown on site in a greenhouse. There is no capability at either location for making parts needed for repair. Again, the Classic Double Tuna-can Hab does not have the space to provide these functions, yet we would send crews in such a cages to Mars. And rather than add additional structures to this complex of one, we would send new Habs *elsewhere* on Mars.

An Alternative Plan

I think we should send to Mars three or more Habs, each differently configured, *to the same site,* along with other ancillary structures, including inflatable ones.

If we do not establish a viable outpost on the first shot,
we may never, ever get another chance.
Exploration will take care of itself.
Other things come first.

For starters, we need:

A food-growing greenhouse large enough to feed a double crew, should the firsts crew not be able to return home when their relief arrives. A diversity of crops, and several species each would be needed to protect from collapse from blight or disease. A greenhouse operation can never be too big. Witness Biosphere II.

✓ **A greenhouse-based life-support system** with air and water recycling with some chemical/biochemical assist, as needed, to be slowly phased out on Mars.

✓ **A complete machine shop and fabrication facility.** Mars is not the Moon. It can have no umbilical cord to Earth for repair, resupply, or rescue. A Mars outpost must make do on a Yolk Sac of parts and supplies sufficient to last for several years and with the capacity to self-manufacture unforeseen needs.

✓ **A complete pocket-hospital.** It is one thing to take a chance with crews on the Moon where return to Earth is relatively simple. The longer the stay, the more certain real medical emergencies, both trauma accidents and other emergencies will arise. A first aid locker won't do.

✓ **An exercise facility**, diversified recreation facilities, support for hobbies, arts & crafts

✓ **A lab where experiments can be made with locally produced building materials** aimed at self-manufacturing as many of the physical needs of the outpost as possible, including expansion of the outpost.

✓ **A Remote Way Station**, a few miles away, where EVA exploration crews could overnight, and to which crew members could retreat for brief periods of quiet rest and privacy in relief of tensions.

Teleoperations Vantage Points on Phobos/Deimos

Nothing leads to failure more surely than impatience. Impatience to explore is an example. Once we have a growing crew at a growing outpost, we will have personnel who can be tasked with the teleoperated exploration of Mars by a whole fleet of mini-rovers and drone aircraft, operated in near-realtime via relays on Deimos and Phobos where the transmission delay is only a fraction of that for the Earth-Moon loop. Manned expeditions could then be sent to the most interesting spots, rather than waste their time on less interesting areas.

Crew expansion leads to economic diversification

Once an outpost, *the* outpost, is clearly viable and at least partially self-sustaining, crew members could be given the opportunity to renew or reup their commitment. Compatible couples could choose to do so, forming the first families on Mars. We have to shut our ears to those who say we can't allow births until we know for sure that humans can survive long term on Mars. Why? Because the only way to know that is to see how the second native born generation turns out, and that means *taking the plunge without delay*. The is no believable ivory tower way to find that out. If humans had always been so "timid," (let's call a spade a spade) we would still be in the rain forests or plains of Africa or in the caves of Europe. It is human to take the plunge, as an exercise of faith in the capacity of the human genetic architecture.

One outpost, repeatedly revisited by supply ships, can grow methodically. As it grows, a more diverse slate of occupations can be supported. Made on Mars consumer goods will be first produced by workers with day jobs in their free time, as cottage industry startups. More and more personnel will be freed from outpost support duties to partake on further exploratory expeditions. Once the needs of outpost expansion can be met with home grown industries, we will have the start of a new civilization on Mars, one making real steps towards an independently viable future. And that, after all, is our Holy Grail.

Bidirectional lessons: MDRS to Mars and Mars to MDRS

Consequences flow forward and backward. We can see from what has happened at FMARS and MDRS that the Hab plan will not work for Mars as the plan now stands. The flip side of the coin is that it is not working even now in the Arctic or in Utah. Yes, we simulate exploration procedures, geology and prospecting procedures, exobiology procedures. But we don't simulate the isolation without hope of relief for two plus years.

It would be both valid and honest to say that the Mars Society has had *to chose its battles*. Some battles are more easily won. The engagement in others seems beyond our grasp as a small nonprofit society. But we ought to advance steadily in that direction, *especially since those battles must be won before we dare set out for Mars.*

Picking a site on Mars – a prime candidate

If we are to settle on just one landing site, we need to pick that site with care. As of now, we have but a foggy start to an **Economic Geography of Mars**, tracing where all the resources are, the logistical advantages, the logical transportation corridors, a priority list for 2nd, 3rd, and following outposts needed for a trading economy on Mars itself. We can expect this hazy map to become a bit clearer by the time the first crew leaves for Mars.

In the meantime, this suggestion. **Pavonis Mons** is one of Mars four largest shield volcanoes. Almost as tall, but not quite as large in area as Olympus Mons, it more than makes up for any shortfall by its location, *smack on the equator.* Its summit caldera rim would be the best spot in the inner solar system to anchor a space elevator (we have to figure out how to avoid Phobos which crosses that path) and its gentle west slope, the ideal place in the inner system for a mountain launch track. The eventual establishment of either would greatly lessen the cost of exports to the Earth-Moon system. More, as a shield volcano much like Mauna Loa/Mauna Kea on the island of Hawaii, it is almost certainly laced with intact lavatubes. In "The Argument from Medicine Lake" (MMM # 74 March 1994, p. 3, republished in MMM Classics #8, pp 12-13) Bryce Walden conservatively estimates that Pavonis offers 333 km^2 = 128 mi^2 of usable sheltered floor space, the size of a major American central city in the one million population range.

But the outpost doesn't have to be on/in Pavonis Mons itself. It could be to the west, between the outer mountain ramparts and the crater Ulysses - call it "Ulysses Junction."

Or it could be east, between Pavonis Mons and the Head of Valles Marineris. While undoubtedly, other sites will have some merit, a location along the equator to either side of Pavonis Mons will certainly be in the running and hard to out-merit. Again, exploration goals and geological and scientific curiosities should score *no* points. They are irrelevant to the overarching need to establish an outpost beachhead of humanity on Mars "securely."

De-marginalizing the Mars Analog Stations

Back to the Mars Society's analog research stations - FMARS is already pre-marginalized by the extreme climate on Devon Island as well as the order of magnitude greater cost of logistics: transportation and supplies.

MDRS has been marginalized unnecessarily, we believe, in the absence of a decision to shield it. Shielding, which will clearly be needed on Mars to attract those unwilling to sign waivers that accept the chances of cancer and risk of reproductive sterilization, is one of those things we have silently put on the list of things not to simulate.

The tall profile of the Hab (again, putting form before function instead of vice versa) makes shielding difficult. A Horizontal ranch-style complex would be much easier to shield. While the landlord, the U.S. Bureau of Land Management [BLM] would not take kindly to wholesale earth-moving, shielding could be simulated in easily removable fashion by bags of mulch, for example.

The thermal equilibrium to be gained would result in a significantly longer field season, now limited by summer heat, and thus make possible a true greenhouse, not the very limited graywater recycling GreenHab system we have. Yes, there are other summer heat related issues: cooling the EVA suits for example. But these too are surmountable.

The existing facility could grow, adding a horizontal crew quarters module, reoutfitting the present Hab structure for a more complete lab (whole second floor deck now given to crew berths, ward room, galley, computer stations) and a much expanded engineering, machine shop, fabrication space on the first floor deck. But where we put what is another question. The priority is to expand, create more usable space.

What about FMARS?

The "first-born" has a special place in the affections of Mars Society members. Devon Island offers a different kind of Mars Analog Terrain. The fact remains that any facility not used full-time is too expensive per man-hour of use to maintain.

It would be a hard choice to take it down, ship it to some other location where it could enjoy full(er)-time use and reassemble and reoutfit it. There are cost-benefit issues that come into play but which can only be correctly assessed if we take the long view. Have we done about all we can do on Devon Island? If so, the time has come to take a fresh new look at this asset and how it can best serve the dreams of the Society.

Relocation of the Arctic Hab to a new home side by side to the Desert Hab and then rethinking how each is outfitted, is one option it will do no harm to brainstorm. The result? A more complete outpost capable of simulating more of the facilities and activities a real outpost must have.

Another idea would be to relocate FMARS to the Orlando or Las Vegas areas as a tourist center. Both MDRS and Euro-Mars have indeed been on display, but in each case, that was prior to interior outfitting. The upshot is that *the visitor did not get a good idea of what it would be like to live and work in such an outpost.* Missed Opportunity!

In an FMARS tourist facility, visitors could see how and where crews live and work, both by walking through a near-identidal layout and through live web-cams to all of the activity areas of MDRS. Such a facility could pay for itself and the whole analog station program by visitor donations.

Then with FMARS retired to visitor duty, MDRS could be logically expanded first by inflatables, outfitted with local materials, then by modules produced and outfitted from (simulated) local (Martian) materials. This would provide a much better model of the way we will need to do things on Mars if we don't want the Mars Program to end as the Apollo one did, as a futile "moment of glory" dead end. We are here to make "History," not an "Historical Moment!"

Summary

The present goal of the Mars Analog Research Station Program is to establish a series of minimal stations at a multiplicity of sites that are each analogs of Mars in different ways. Many things cannot now be modeled or simulated because of the Procrustean limitations of the form/shape/size of the Hab design based on transportation constraints. It would seem better to go beyond the simulation of exploration procedures and the testing of equipment. We need to phase in simulation of transition from initial "bare bones" outpost into a viable and permanent beachhead.

Establishment of a more capacious foothold with endurance capacity is much more important than butterfly sampling of many locations. Exploration, and much, much more of it, will be best guaranteed by establishment of a viable beachhead as the primary goal of a Manned Mars Mission program.

Currently, the separate Mars Foundation works on its own to find pathways to settlement. The Mars Society needs to collaborate with the Foundation to vastly improve its analog program., which is currently aimed only at the exploration of Mars, not settlement.

If we want to simulate what we will need to have on Mars, we must grow MDRS as we would the first outpost on Mars.

It's all so simple, really. **<PK/MMM>**

[We realize that this article will prove to be quite controversial, "cart upsetting." But it often happens in any movement that a time comes when we must stand back and ask, "are we still on the track? Or did we get off it some-how? If so, how do we get back on the path to our dreams?"]

New Words for our Vocabulary from the Martian Frontier

blue, green passion, in synch with MarsTime
fierce independence, respect for outdoors
resourcefullness, elbow room makers
self-reliance, biosphere-focused
creativity, the intent gardeners
forge
of Mars
missing colors, cold to bitter
bit longer day, no biosphere
very long year, no calls home
zoo of seasons, long trips out
no-breathe air, resupply delays

Slang, Figures of Speech, Names

by Peter Kokh

Frontiers have always expanded our Languages

There are those who loathe the introduction of new words into the language. But its enormous capacity to adopt new words and make them its own is a major reason why English is the most *widespread* language on Earth. Indeed, Dictionary publishers accept this as a matter of fact.

All past frontiers have contributed a wealth of new words, phrases, and names to their languages. America, the American West, Canada, Australia, New Zealand, South America and other newer adopted homelands have all contri-buted and continue to do so. Stretching old words to convey new meanings can only go so far.

As we move out into frontiers beyond Earth's familiar shores, we should accept and encourage coinage of new words and expressions, not fight futily against them. For it will be no different as we establish ourselves on the Lunar and Martian and asteroidal frontiers ahead.

New Words and Expressions from the Mars Frontier

There will be new types of structures, new occupations, new sports, new hobbies. There will be new kinds of dangers, and new strategies to meet them. New strange environments will contribute many new terms. New time reckoning systems and new holidays and festivals will bring new terms and phrases. Seasons only crudely analogous to any on Earth and new weather phenomena as well as ways the settlers find to deal with them will give birth to new words and figures of speech.

New human places will generate new place names as imaginative, colorful and varied as have the new terrestrial frontiers previously settled. It could hardly be otherwise.

We have already chosen new class names for types of geological features special to Mars. See the next page. As we explore Mars, we will had to the list of words that denote topographical landscape features unique to Mars.

Habitats and Transportation

Mars will see the birth of new types of architecture and new types of construction. Martian homesteads will have new features, new types of rooms, new types of furni-ture and furnishings. The new Martians will develop new kinds of sports and sporting activities, new kinds of hobbies and new kinds of art media and craft.

The same goes true for new, evolving types of transportation designed for the Martian environment. New types of wheeled vehicles private and public, of trains, even of aircraft will evolve to make the Mars civilization as mobile as our own. And just having to deal with new kinds of obstacles, emergencies, and vulnerabilities will generate new expressions and figures of speech.

Elements of a Unique Martian Culture

Any frontier gives birth to its own unique holidays and festivals, events that promote group solidarity and cohesiveness. These will be special items on a new Martian calendar. On that score, many have attempted to invent and publish Mars calendars, hoping to have the honor of creating the one adopted by the pioneers. The pioneers, and not us, not the Mars Society, will pick their calendar and their timekeeping system. All we can do is supply models for them to consider.

Mars has its own unique rhythms: a slightly longer day, a nearly doubly long year, and very uneven season lengths. Sol, meaning Sun, now designates the 39 minute longer Martian day. I must say that this choice is reprehensible and I harshly censure those who picked this term. Sol means the period form one noon to the next, and as such applies to ANY (yes, I am shouting) noon to noon period on ANY planet or satellite, not just Mars, and no one had the right to reserve it to Mars alone. Sorry, pet peeve big time.

The same goes to economic and political systems. The Mars Society Civilization & Culture Task Force, at least for the period in which I tried to moderate it, attracted many utopians slow to realize that when all was said and done, it would be the pioneers themselves who will choose and have the sole right to choose any and all systems by which they want to live. Mars will be their planet, not ours. It's our lot to prepare, no more.

The arid desert rock and soil tone pallet of mars will also generate new words. This palette is very narrow and introduces serious color deprivation. The eye wants to see more, and for many colonists, the priority will be to surround themselves with the Mars Missing Colors: blues and greens especially, but also yellows, reds, purples, and even blacks and whites. They will introduce missing colors into their home decor, into inside window box planters so that they can look at the barren exteriorscapes through the reassuring filter of green foliage and floral colors. For fast safe identification of suited personnel and vehicles out on the surface suits, signs, and vehicles will hardly come in colors that blend into the background. Unlike the case on Earth, Mars camouflage will have no greens anytime soon!

Marsspeak, whether it is an off shoot of English, of some other terrestrial language, or a new construct will have terms to distinguish newcomers from those born on Mars as well as those who have lived on Mars for some time. There will also be words and expressions to describe the isolation that comes from launch windows two plus years apart and from message transmission lags of 6-40-some minutes.

That the new Martians must live off a Yolk Sac of supplies and parts, and not at the end of an umbilical cord (as is the case for Lunar settlers) will give rise to figures of speech as well.

Whatever language or languages we bring to Mars will evolve with the frontier. Pull a Rip van Winkle and awake a hundred years from now to a made-on-Mars movie, and you will be hard put to understand. Life moves on, and language moves on with it.

Words, Expressions, and Names from the Mars Society's Analog Research Station Program

The experiences of volunteers at the Mars Society Analog research Stations will also contribute words and phrases that have some real chance of surviving on the actual frontier of Mars. There may be place names such as *New Boulder*, *New Resolute*, *New Hanksville*, to mention some of the more obvious choices.

There will also be names and phrases that will ring a bell only with FMARS and/or MDRS veterans.

"Mommy, why is the road from the spaceport to the settlement called New Cow Dung Road?"

"Daddy, why is the first paved highway on Mars designated Highway 24?"

"Daddy, why is that flat mountain top named Factory Butte? There's no factory up there, is there?"

And so on. At least we veterans would be pleased to know that some of our experiences may be immortalized in *MarsSpeak* one day. After all, our hard work is aimed and dedicated to making it possible for the real drama to unfold in the not too distant future.

</MDRS>

From MMM #133 March 2000, p.1

Mars will Forge those who Pioneer it

Alien beauty, endless monochrome horizons, thin breathless air, trans-Siberian cold, a tad longer day, doubly long year, irregular seasons, remote from Earth. Mars! Here is a world that will take its pioneers and reshape them to the core. In the end Mars will tolerate only "its own kind of people." And Mars will make them "the best."

More Relevant Readings from MMM #s Past

MMM **# 41** December 1990, p 6. To Inject a Unique Flavor into Martian Settlement Culture, add the Romantic Touch of Old BARSOOM

MMM **# 73** March 1994, p 5. Canal Names of Yore

MMM **#133**, March 2000, p 3. Seeds & Wellsprings of Martian Culture, P. Kokh: A One-Sided Mars Palette; p 4. Cont.: Mars Time: A Tad Longer Day; p 5. Cont: A Doubly Long Year; Diverse Seasons Lengths; p 7. Cont.: Outdoor Mars: Thin Atmosphere, Cold Climate; p 8. Cont.: No Open Water; No Biosphere

Red Mars	Muddy Mars	Green Mars	Blue Mars

Oops! We forgot a Color!

"So you want to terraform Mars? Wake me up when you're all done!"

Don Foutz

By Peter Kokh

We can begin to breed Mars-hardy plants even now, here on Earth, in conditions where the needs of the most cold-hardy and arid-hardy Earth plants meet present Mars conditions "halfway," so to speak. See our previous article on "Redhousing," MMM #93 MAR '96 [MMM Classics #10]

But we won't be very successful in introducing them to the unprotected surface soils of Mars until a) the atmospheric pressure has been increased by an order of magnitude or so (to 7-10% Earth-normal) and b) until we are have bodies of liquid water (seas) which evaporate, produce rain, and drain back into the same or other seas.

And guess what happens when you rain on exposed plant free soil? You get mud, lots of mud, too much mud, enough mud to make all surface operations very difficult and *discouraging*. Anyone who has served at the Mars Desert Research Station knows that all too well.

Now that poses quite a challenge to devotees of Kim Stanley Robinson's epic Mars Science Fiction Trilogy "Red Mars, Green Mars, Blue Mars." It challenges those also who have become attached to the Mars Society Tricolor.

The challenge? Either invent and develop processes to "fix" the soils of Mars before the first rains fall, *or* change the tricolor to a 4-color flag. ***No middle ground.***

Now it may be possible to fix the soil, and an ideal location for experiments on a small scale is the Mars Desert Research Station outside of Hanksville, Utah. Small plots a few yards/meters square could be treated without significantly violating the terms of our lease with the U.S. Bureau of Land Management [BLM].

What would you use as a fixative? It had better be something we can easily reproduce on Mars, perhaps something *eventually biodegradable* from the ingredients in Mars' own atmosphere; something *cheap enough to produce on an enormous scale*. That means not only that the involved elements must be easy enough to produce with low energy inputs, but that the process of producing the fixative from them must be inexpensive on a vast scale.

We offer no suggestions, just make the challenge. ***Find a solution or change the flag!*** There are benefits here and now for a solution. We could treat the area immediately surrounding the MDRS Hab and contiguous structures. That will greatly reduce the tracking of mud into the Hab and the consequent chore of cleaning it up, over and over again.

We'll even name the fixative after you! **</MDRS>**

MMM #194 - APR 2006

Fired Earth Structures as a Model for Moon & Mars?

At the California Institute of Earth Art and Technology in Hesperia, CA, north of San Bernardino, creating fired earthen structures for people on Earth, *as well as for future people on the Moon and Mars* is taken seriously. The structures do make one think somewhat of the plans of the Mars Foundation for building on Mars out of local materials. But many challenges must be overcome. *below.*

Creating STRUCTURES in Lunar Bedrock

Madhu Thangavelu, Conductor, Space Exploration Architectures Concept Synthesis Studio,
Dept. Of Aerospace and Mechanical Engg. School of Engineering and the School Of Architecture,
University of Southern California, Los Angeles, CA 90089-1191 email: thangavelu-girardey@cox.net

Abstract

Rock structures have been used on Earth for habitats and related infrastructure since time immemorial. This paper proposes the concept of using moon rocks, both raw and machined, to build permanent lunar colony infrastructure elements. Merits and challenges are listed.

Introduction

Highly efficient, long-lasting and successful habitats and related structures built of rock have been erected on Earth for thousands of years. While specimens abound all over the world, fine and lasting examples include the pyra-mids of Egypt, the pre-Celtic and cave structures of Europe, the ziggurats of central and south America and the temples of Greece, south east Asia and India. They were all built many, many centuries ago, and some of them are quite serviceable even today.

The Moon presents a highly rocky structure that appears just a few meters below it's gardened surface. It should be possible, with the proper tools and methods, to utilize this resource for building up the permanent lunar colony infrastructure.

Combating The Lunar Environment

Hard vacuum, Galactic Cosmic Radiation, high energy solar particles, large thermal variations during the lunar diurnal cycle and micrometeoritic showers make the lunar surface a very harsh environment for humans to inhabit without sufficient protection.

It is possible to provide a pressurized environment using an airtight vessel such as a hard or inflatable module. However, substantial physical matter(mass) is needed to effectively shield against temperature swings, radiation and the constant bombardment of micrometeorites. Carrying the required mass of shielding materials along from Earth is prohibitively expensive and impractical. Therefore, ideally, an initial lunar colony might do well to situate a pressurized habitat within a naturally protected and easily accessible location such as a lateral fissure or under an overhang within a crater. The next best but energy consuming, messy and risky shielding option might be to pile up the required thickness of loose material around a pressurized habitat.

Rock Structures

- A. naturally occurring and
- B. artificially built

Naturally occurring rock structures include, randomly distributed, geologically formed hollows or cavities on the terrain including craters, caves, gorges, volumes under rock overhangs, ravines and so on.

Volcanic, seismic, meteoritic, (for the Moon) as well as aqueous and aeolic processes(for Mars and other bodies with an atmosphere and surface liquids) are among the agents responsible for these formations. Many ideas have been proposed for utilizing these formations for extraterrestrial habitats.

Artificially built rock structures for the Moon are the subject examined in this paper. They include the use of raw or unimproved rock in various forms as well as tooled or machined rock for building permanent habitat structures and surroundings.

Rocks –Tools – Uses

Our hard data about lunar rocks comes primarily from specimens returned by Apollo and Luna missions. Moon rocks fall into four groups. They are basaltic volcanic rocks, pristine rocks, breccias, impact melts and lunar soil.

Using appropriate quarrying, transportation, tooling and laying/setting systems that include rock splitters, transport vehicles, crushers, shapers, polishers, connectors and robotic integrators, a very useful building capability may be evolved on the Moon and other planets, that might find extensive and highly effective use in the expedient and permanent build-up of extraterrestrial colony elements. Walls, aprons, towers, dome exteriors, roads and tunnels, landing pads and other exposed platforms are some of the elements that might make use of this technology. More than half of all the materials needed for building a colony such as the one depicted in the image below (Figure 1) could be derived from rock, both raw and processed.

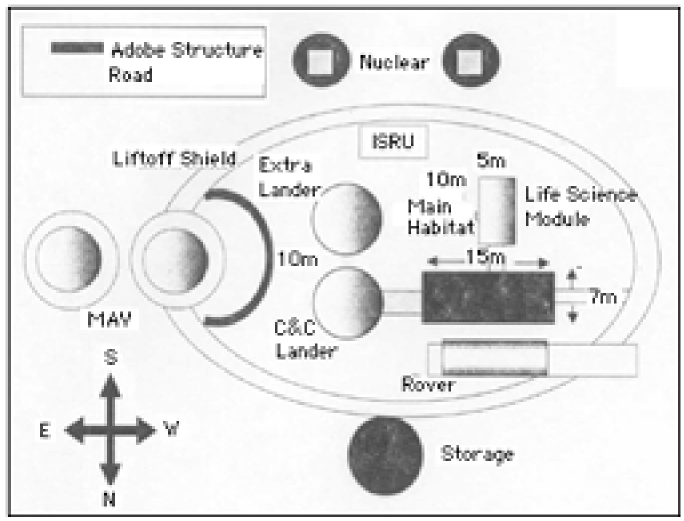

Fig. 1. **Hesperia Lunar/Mars Base Site Plan Phase I**: More than half of all the materials needed for building a lunar colony could be derived from rocks. Illustration by Dr. Anita Sengupta NASA/JPL

Technology Continuum Dilemma

Mankind has been building complex habitable architectures for millennia. The resilience of such structures are partly due to the materials used but their habitability and serviceability are mainly attributable to empirically tested, evolutionary methods employed in their design and creation.

Space Architects, Designers, Engineers and Builders may all do well to expand their world view about man-made lunar structures. The highly constrained, narrow, often trendy, state of the art high technology driven mind-set will have to accept and be inspired by a more broad-minded "Technology Continuum" philosophy, seeking solutions from age old and time tested concepts for building spaces for habitation and adapting them appropriately for extra-terrestrial applications.

Merits and Challenges

1. Rocks of varying types, shapes and sizes are abundantly available on the Moon.
2. The low gravity allows for easier handling of massive blocks from quarry to tooling and placement.
3. Raw, unmachined rocks may be sorted/graded and neatly arranged/packed to create a variety of useful structures including shadow walls, radiation shielding, paving, glare and backscatter mitigation, dust traps and covers,
4. and elevated foundations and rough hewn platforms using age old "dry packing" technology.
5. Machined blocks may be precision-cut into slabs, blocks, bricks, columns and beams that can be used as exterior and interior load bearing and finishing elements in lunar colony buildings and related infrastructure.
6. Having been created and subjected to the space environment for geological time, they are very durable in the extraterrestrial environment
7. Existing quarrying and tooling machines may provide valuable insight in the design and operations of robotic equipment that can be built and remotely operated to build up a warehouse inventory of rock products and material well in advance of human arrival to permanently settle the Moon.
8. The combination of low gravity, the absence of of lateral loads (wind, seismic activity) and precipitation, (forces that constrain the size and form of Earth bound structures) may allow "dry packed" lunar structures much more morphologic freedom, with the possibility of constructing very tall and slender structures, long, uninterrupted canopy spans and so on.
9. For reasons of landing safety, conventional primary landing zones for IOC bases are proposed in smooth, level terrain, free of rock fields and outcrops. Ironically, rock strewn regions around fresh craters as well as sites rich in rock outcrops would offer ample opportunity to collect, tool into shape and even sculpt building structures employing low energy expenditure methods. Such sites may also harbor natural formations to protect habitats from mm, radiation and effects of thermal cycling.

Challenges

Quarrying, tooling and finishing create substantial high energy debris that must be curtailed at the source. Particularly on the Moon, these particles can easily approach or exceed orbital velocities and thus create environmental havoc. So, it is important to process rock in a careful environment.

Having been created and exposed to vacuum for geological time, lunar rock is stable in its natural, mostly anhydrous composition. Its use in relatively humid habitat interiors may require some study and possibly special processing to maintain strength and stability.

Extensive testing alone can provide the data needed before commissioning these rock products for lunar building applications. So, more testing of lunar material is essential to identify merits and limitations, and appropriate use of rock for building Moon colonies and related infrastructure.

Conclusion

1. Humanity has successfully built rock structures and habitats on Earth since time immemorial. We are continually discovering prehistoric civilizations through hewn and processed rock structures still standing all over the world, the only surviving remnants of their culture. This is indeed a testament to their durability.
2. Lunar rock materials are plentiful on the Moon. They may be used for lunar colony buildings. Raw, unfinished rock has several exterior uses while tooled rock may find extensive application both for load bearing structures and also for finishing exteriors and interiors.
3. Existing tools and machinery used on Earth may be adapted for robotic operation on the Moon that could build up a lunar rock products warehouse inventory of colony building materials well in advance of human arrival.
4. Space architects, engineers, designers and builders may do well to adopt a "Technology Continuum" philosophy and broaden their palette of high technology materials and artifacts to include timeless ways of building. We must utilize the best materials and practices handed down over the millennia as we proceed to build meaningful, efficient and aesthetically becoming permanent structures at the final frontier.

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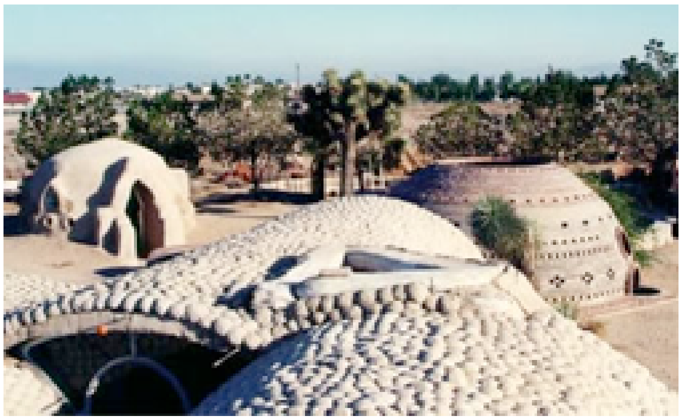
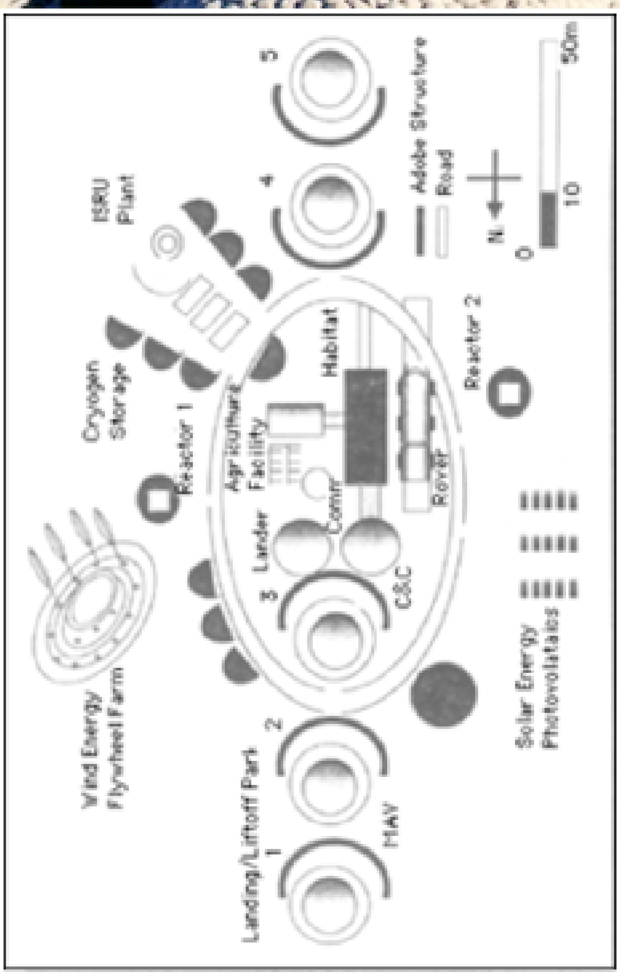
Hesperia Calearth Photo Gallery





Hesperia Lunar/Mars Base Evolved Site Plan

A Lunar EXPLOSIVE

by Dave Dietzler pioneer137@yahoo.com

Explosives usually consist of organic chemicals containing hydrogen, carbon and nitrogen. On the Moon these are rare and we made need large masses of explosives for rock blasting. Rather than waste H, C and N that are so valuable for life support systems for making explosives we might be able to use abundant magnesium and oxygen. John Wickman of Wickman Spacecraft & Propulsion Company [http://www.space-rockets.com/wspc] determined that magnesium and LOX don't make a good monopropellant because this mixture was shock sensitive and detonated. This might be a blessing in disguise. Magnesium metal tanks might be loaded with a slurry of magnesium and LOX and detonated with an electric spark plug.

Magnesium burns with 10,640 btu per pound. Mixed with the correct amount of oxygen at a ratio by weight of 3:2 we'd get 7090 but per pound of Mg/LOX mix. One pound of TNT releases 2300 btu and one stick of dynamite 2000 btu. So this might be a decent explosive. Flame speed must also be considered. Hydrogen burns with 61,000 btu per pound but only has a flame speed of 8 ft/sec. Gasoline has 20,500 btu per pound and has a flame speed of 70 to 170 ft/sec. The plastic explosive C4 and RDX, chemically similar to TNT, both have a detonation or flame speed of about 27,000 ft/sec.And TNT has about 23,000 ft/sec. The actual explosive properties of Mg+LOX must be determined by experimentation.

The volume of one pound of magnesium is about equal to the volume of 9.2 fluid ounces of water and 2/3 pound of LOX would be equal to about 9.4 fluid ounces of water. So a small tank of Mg/LOX with about 7090 btu and roughly the energy of three sticks of dynamite would be a little bigger than a one pint jar. How much explosive power it really has because of its flame speed is something we must research. A valuable discovery may await us.

NOTE: When ground up into a powder a pound of magnesium dust will occupy more volume than in solid form because there are spaces between the particles, but the actual volume of the particles without the spaces is the same as the solid block from which it was ground up. LOX will fill the spaces between the particles and some will fill extra volume, so the simple volume calculation for the explosive slurry based on density alone is valid. When the slurry is agitated and the magnesium particles dispersed throughout the LOX the volume of neither substance based on weight and density does not change. As for surface tension effects or the contraction/shrinking of magnesium particles in super cold LOX, those are details to be worked out by experimenters.

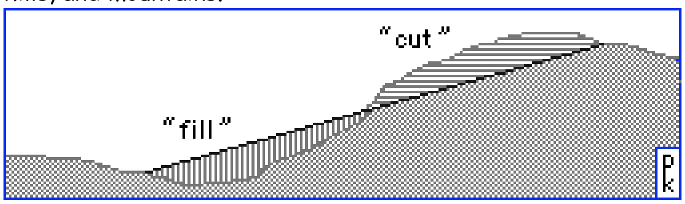
Let's hope some college students at a school of mines or somewhere read this and pick up on it or Wickman does a little research if he hasn't already. This should not be an expensive project for people with access to LOX who know how to handle explosives safely. **<DD>**

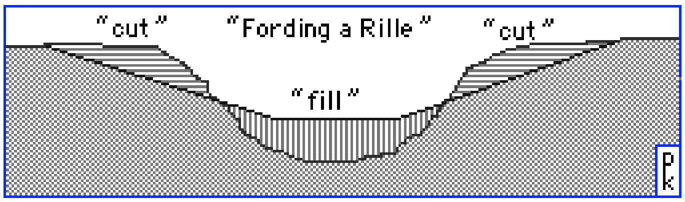
Constructive Uses of Explosives on the Moon

By Peter Kokh

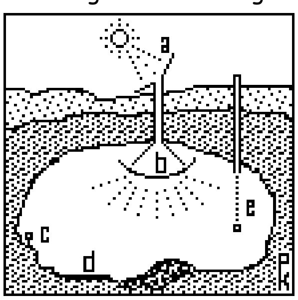
Some, adversely conditioned by the use of explosive devices in war, all too much in the news in our times, may be slow to see the value of explosives on the Moon. But any tool has positive productive and creative uses as well as negative destructive ones. Explosives are no different. We simply have to look at their positive use in our own down-to-Earth technology.

Frontier road construction crews will need reliable explosives for "cut & fill" operations to make roadways more level, minimizing the grade elevations when crossing ridges, hills, and mountains.

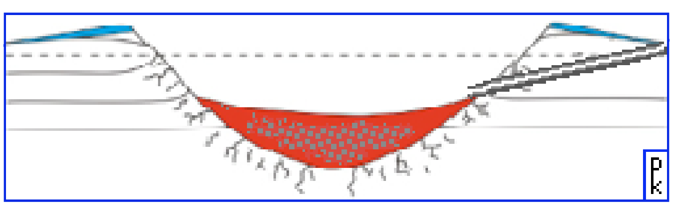




Teleoperated machine site preparation for new outpost sites may need explosives to remove boulders from the location, or to excavate furrows in which to set Habitat modules so that they can be more easily covered with a shielding blanket of regolith.



Boring tunnels through Crater rims for road way access between the crater floor and surrounding areas. We may need to bore tunnels through mountain ramparts as well to avoid lengthy, time-wasting circuitous detours.



Sub surface mining operations will depend on the availability of explosives to dig mining shafts, drifts, and stopes, should we detect by surface soundings, or by drill cores, the presence underground of valuable ores not found in equally concentrated form in the pulverized surface blanket (regolith). **<MMM>**

By Dave Dietzler pioneer137@yahoo.com

1. We have thought for a long time, based on our theories of stellar and solar system formation, that planets must orbit other stars.
2. In the sixties [we thought] we discovered large planets orbiting nearby red dwarfs by the "wobble" method.
3. In the nineties we did discover large planets orbiting stars like our Sun by the doppler method.
4. We have yet to discover planets the size of Earth orbiting other stars. The Terrestrial Planet Finder that will launch in 2014 will use advanced imaging technology to do this. It will even be able to analyze light from terrestrial type planets to detect oxygen and water vapor. We will be able to determine the mass of these planets and their distance from their suns to determine whether or not they are in the life zone.
5. Our next step will be to construct more sophisti-ated instruments, perhaps huge space telescopes, that can detect the spectra of things like chlorophyll or even Indus-trial pollutants. Perhaps we will develop instruments that can image these worlds; even see their continents and oceans.
6. Next, interstellar probes will be launched to inspect these worlds at close range. The most interesting targets will be the ones that are in the life zone, have oxygen and water, and possibly indications of life. The probes will probably be laser sail propelled or mag-sail/ particle beam propelled, and they will brake into the target solar system with magnetic sails. They could maneuver around in the target system with magnetic sails and make close approaches to the planets we are interested in, even go into orbit around them and drop small landing probes to the surface. These probes will be controlled by AI computers capable of independent decision making since they will be to distant for radio control from Earth.
7. Finally, manned missions to the stars.

Life-supporting planets may be rare

Mercury, Venus and Gas Giant planets cannot support life, but are interesting for other reasons. Earth sized planets outside the life zone will either be frozen or so hot they become like Venus. Marslike planets inside the life zone might support life. We don't even know for sure whether Mars has life now or did in the past and this is a question we hope to answer in the 21st century. The discovery of life on Mars, past or present, would be of great significance, and the discovery of life on planets orbiting other stars would be too. Earthside planets may be found with life at various stages of evolution like mere algae in the seas, plant and animal life in the seas, life on the land from higher plants to higher animals; but the greatest discovery would be intelligent life.

Do we know enough to define Intelligent Life?

How do we define intelligent life? Certainly, apes, dolphins and some other species indicate that they have some intelligence, but we hope to someday find creatures much like ourselves. They might be similar to highly evolved mammals or birds or even insect like creatures. Primates are not the only candidates for higher evolution. Bears stand upright at times and use their forepaws. Some ant species have been shown to engage in group work activities! To evolve to large body and brain size insects would have to develop a better breathing system and probably shed their exoskeletons in favor of endoskeletons. *Unlikely!*

Can civilization develop in the Ocean?

Octopi have been shown to engage in intelligent behavior but it is hard to see them existing on land, but what if large brained octopi evolved out there somewhere and built a fantastic civilization beneath their sea? They wouldn't have fire, metal working and electricity to be sure*, but they might know how to use harder stones to carve softer stones or corals or even polar ice into various imple-ments and habitations.

For such creatures, exploring the land would be like our adventures into the deep sea or outer space. They might know how to harness other creatures found in the seas or even have advanced biotechnology. Certainly they would have vast knowledge of life in their seas, foods and medicines; language, something equivalent to poetry or song, and folk lore, even religion, especially if they are social creatures.

How could they store knowledge other than by memorizing and passing knowledge down generation after generation? What kind of writing could survive underwater? Perhaps they could make elaborate stone mosaics held together with some natural adhesive that last for decades before dissolution in water and are copied over and over again like books once were. If the evolved endoskeletons they might eventually evolve into land creatures and create advanced technology with fire, metals and electricity like the octo-spiders of Sir Arthur C. Clarke's ***Rama*** novels.

Technologically advancing civilizations

Finding civilizations at a similar level of technological development will require quite a bit of coincidence or "good luck." We could transmit radio or laser signals at Earthside worlds and wait for a reply, but will they be listening at the right frequency?

So many factors were involved in the evolution of human civilization and technology, from leaving Africa and learning to live in the colder climates to the necessities of war, that we cannot expect other intelligent creatures to have followed the same pattern. Perhaps man with his phallic aggression and creativity is one of the few creatures who would build rockets and star ships. Most creatures on Earth are so well adapted to their environment that they don't need tools, but man was poorly adapted to his environment physically and used his brain to adapt his environment to suit his survival and reproductive needs by making tools, weapons to fend off large predators, building shelter, using fire, etc.

Other creatures in the universe, even very intelligent ones, might be so well adapted to their environments that they did not need to invent technology and subsequently even explore space. Their rate of reproduction might not be nearly as great as humans.

For us humans, year round fertility and sex drive has almost been a curse upon us that has lead to overpopulation and natural population checking mechanisms like epidemics, famine when local food supplies were outstripped and even war to keep us from over running nature for millions of years. This has also forced us to invent hunting, livestock keeping, farming, food preservation and medicine.

Creatures who mate only during the mating season and produce much smaller broods would not endure the cursed fertility that we have, mythologized as original sin, and would not have to invent so many things to promote the survival of their offspring. So while we might not be alone in the universe when it comes to life itself, even intelligent life, we might be very rare when it comes to technological civilization and even rarer when it comes to space faring civilization.

It isn't hard for me to believe that an intelligent species with much lower reproductive pressure could stay in it's equivalent of Africa for hundreds of millions of years with a technological level no higher than that of Egypt, as long as their planet did not undergo major climatic changes during that time. They might be a lot less curious than us apes too! These creatures might never reach into space or have radio or laser communication systems but they could offer much in the way of art, philosophy and theology.

We must explore Mars to answer the question: "Does life of any kind of life emerge on other worlds?" We must industrialize the Moon and solar system if we are ever to venture beyond into the galaxy. If we are to become the primary star faring civilization in this arm of the galaxy, it will be our duty to protect indigenous life on other extrasolar planets. We will go for the quest of knowledge and not to conquer, colonize and swamp space with humans, although there are probably worlds where we can coexist with native life, and worlds like the Moon where we can live without conflict. **<DD>**

Editor's Remarks:

The aspects of "The Question," "Are we Alone?" are so manifold and convoluted that it would take a fair size book to begin to treat them all. In a short article, no writer can do more than touch on a few considerations of interest to him/herself. Certainly the aspects touched on here are significant.

What kind of worlds are suitable for intelligent life? We naturally define intelligent in terms of our own achievements in using our brains and hands to adapt to our world and adapt our world to ourselves. We remain "generic," unspecialized in any of the ways that risk setting a course for an evolutionary dead-end. We can at will specialize ourselves by choosing our tools, leaving our physical interface with nature as universal as possible.

We are air-breathing land creatures. Could technology-using species arise in the sea? *I think the author puts limits on a sapient octopod race that need not apply. The "Wisefeet" could stay in the water, yet build rafts on top of which they could conceivably use fire and other tools that require air. *Our own* Octopi have two strikes against them as to further advancement:

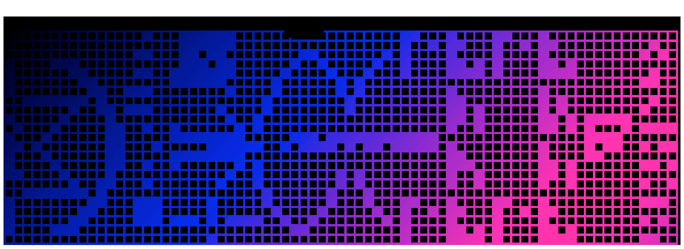
1. a very decentralized nervous system, and
2. copper-based blood instead of the 20 times more efficient iron-based blood we have.

Scratch those two misturns, and who knows how far invertebrate intelligence could go?

The chances that we will *"find"* intelligent life elsewhere are not as good as the chances that there *"is"* intelligent life elsewhere. It's not that civilizations do not want to be found, though that may not be an uncommon outlook. It's simply a question of technology and economics: *it is far easier and cheaper to listen effectively, than to send messages effectively.* To send with real hope of being heard, requires a centuries' long cathedral-building project of extreme and unquestioning dedication: one must broadcast in all directions of the sky for decades, centuries, millennia, or even more. *Civilizations will be as far apart in time, in any given area, as they are apart in space, at any given time.* **‹PK›**

Relevant Readings from MMM #61, DEC 1992

p 4. Are We Alone?;
p 5. What is a "Humanoid"?
p 6. Galactic Topography 101;
p 7. The "Heliades Cluster"?
p 8. Sending interstellar signals;
p 9. Cheshire Messages



MMM #195 - MAY 2006

From Laika to a Lunar Prospector's Best Friend

As many a criminal has found out, dogs have a keen sense of smell. Could future prospectors put that talent to work on the Moon to find trace elements? Perhaps not, but maybe a robotic sniffer with senses even keener could help. We are using new "DART" technology here on Earth. What's needed is for some inventive space enthusiast to adapt this new technology for lunar vaccuum. See *below.*

Solar Thermal Rocket Engines

By Ben Smith terranexplorer@yahoo.com

Solar thermal rocket engines (abbreviated STRE in this article) are an exciting propulsion option, especially for Lunar settlement and Lunar-Earth space development. The great promise of STREs is the fact that the only inputs are sunlight and a reaction mass. Ideally the reaction mass will be obtained from Lunar resources (to cut down on launch costs and to provide Luna with an income producing export). Lunar produced liquid oxygen could be the propellant used to propel spacecraft throughout the inner solar system.

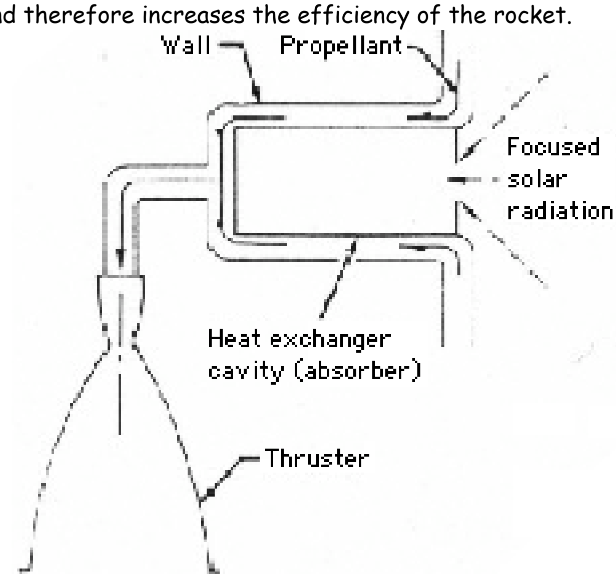
A solar thermal rocket engine is a form of spacecraft propulsion that uses concentrated solar energy to heat a reaction mass (the propellant used by the rocket to produce acceleration) to high velocity. The fast moving reaction mass is then expelled from the vehicle to produce forward thrust (According to Newton's 3rd law of Motion, for every reaction there is an equal and opposite reaction. Therefore, thrust equals the mass of the reaction mass times the acceleration of the reaction mass).

Unlike chemical rockets, STREs use sunlight to heat its reaction mass, instead of a chemical reaction. This makes STREs inherently safer than chemical rockets because they do not rely on a controlled explosion for heat, and liquid oxygen will not explode without a fuel source (oxygen is an oxidizer). Mirrors are used to concentrate solar energy which is then used to heat the reaction mass. The heated reaction mass is exhausted through a conventional rocket nozzle to produce thrust. The exhaust velocity of the reaction mass is related to the surface area of the mirrors, the local intensity of solar radiation, the thermal limits of the heat exchanger (if one is used), and the mass of the reaction mass. Relatively few moving parts are necessary, increasing the reliability and safety of STREs.

Hydrogen is often proposed as the reaction mass of choice because it has the lowest molecular mass (the sum of the atomic masses of all the atoms composing a molecule. Hydrogen has a molecular mass of 1.0 gram/mole.) of any element. Lighter reaction masses have higher exhaust velocities and give the rocket a higher specific impulse (the change in momentum per unit of mass of propellant. Noted as Isp). Specific impulse is a measure of how much thrust can be obtained from a fixed mass of propellant and is used to compare the efficiency of various propulsion methods, the higher the Isp the more efficient the engine. STREs using hydrogen as a reaction mass can reach a theoretical Isp of 900-1200 seconds depending on the design (WordIQ.com). In comparison, the Space Shuttle Main Engine, the most efficient chemical rocket engine in use, has an Isp of 465 seconds. The ion engine on Deep Space One produced an Isp of 3000 seconds but required a long period of acceleration to reach high velocity (Hirata). Hydrogen would be an unsuitable propellant due to its scarcity in Lunar regolith. Data was unavailable regarding the potential Isp of liquid oxygen as a reaction mass.

There are two basic types of STREs, indirect heating and direct heating. Both types would use similar mirrors, reaction mass, and exhaust nozzles but differ on how the energy is transferred to the reaction mass.

The simplest type of STRE uses indirect heating of the reaction mass. This involves focusing solar energy onto a heat exchanger. The reaction mass is then passed over and/or through the exchanger where it picks up energy, expands, and accelerates. Some designs have the heat exchanger open to space, but the more efficient designs have tsolar energy pass through a high tempera-ture quartz window instead of an open hole in the side of the rocket. Enclosing the engine increases pressure inside the rocket and therefore increases the efficiency of the rocket.

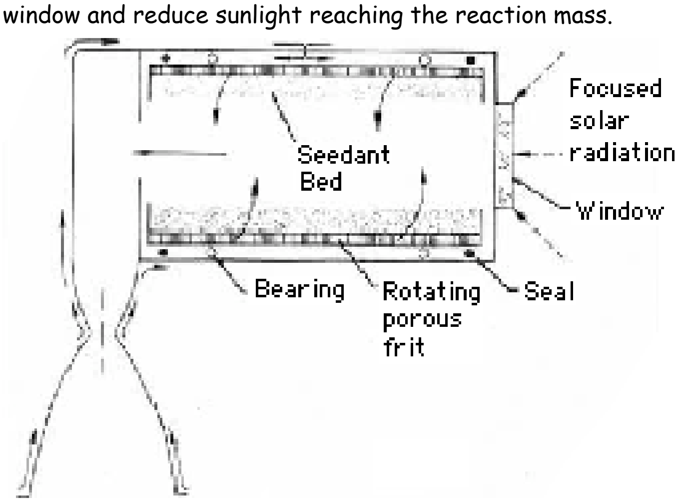


Indirect solar thermal engine. Source: NASA SP-509, “Space Resources – Energy, Power and Transport”, 1992, p. 162. Image: Permanent: http://www.permanent.com/t-steam.htm

The primary drawback to indirect heating is that the maximum temperature of the reaction mass is limited by the maximum material temperature of the heat exchanger. Almost all known engineering materials melt above 2500 degrees Celsius, making this the absolute temperature limit for the reaction mass also. Current designs use a refractory material such as tungsten, rhenium, or graphite and operate around 2200 °C Because of this limitation, indirect heating designs are limited to an Isp of 800-1000 seconds (WordIQ.com). There are several theoretical designs using fluidized silicon beds that may be able to retain substantially more thermal energy.

The other type of STRE directly heats the reaction mass with concentrated solar energy. In this method, concentrated sunlight is directed through a high tempera-ture quartz window directly into the reaction mass. Since there is no heat exchanger to limit the maximum temperature, specific impulses approaching 1200 seconds are theoretically possible (WordIQ.com). The drawback of this method is that it is more difficult to heat a gas (the reaction mass) than it is to heat a solid (the heat exchanger). A solution to this problem is to seed the reaction mass with particles of tungsten or several forms of carbides. These particles absorb the energy and impart it to the reaction mass via convection and conduction.

The drawbacks to this solution are that the particles will reduce the Isp of the engine and have to be replaced if they are allowed to vent with the reaction mass. The current design to prevent the loss of the particles is to use a rotating bed (Shoji). In this design, the reaction mass flows through the porous walls of a rotating chamber where it absorbs the thermal energy from the particle seeds. The seeds are retained on the walls of the chamber through centrifugal force (technically not a force but the effect of the inertia of the seeds, causing them to move away from the center of the chamber). This prevents the particles from exiting the rocket along with the reaction mass. While more efficient than indirect heating, this design is consi-derably more complex, expensive, and massive. There is also the danger that the seed particles may stick to the quartz window, causing localized heating and potential failure of the window. Loss of pressure causes the engine to stop working. Contact with seed particles may also scratch the window and reduce sunlight reaching the reaction mass.



Direct solar thermal engine. Source: NASA SP-509, "Space Resources – Energy, Power and Transport", 1992, p. 163. Image: Permanent at http://www.permanent.com/t-steam.htm

As efficient as STREs are, they do have several operating restrictions. STREs produce less acceleration than chemical engines, making them unsuitable for boosting out of strong gravity fields (like the Earth's surface). Data was unavailable as to the possibility of using STREs to lift from the Lunar surface. This is an area we should investigate. Also, large mirrors are needed to concentrate the sunlight and generate the intense heat necessary for engine operation. While solar intensity in Earth space is 1.4 kW/m2 the engine will still need mirrors that are up to 100 meters in diameter. Such large mirrors dictate that STREs can only be used in vacuum and beyond Low Earth Orbit (where atmo-spheric drag is still a factor, and orbital debris a hazard.). Solar energy at Mars orbit is 45% that at Earth orbit, making STREs less practical beyond Earth orbit.

Only two serious attempts have been made to turn STRE theory into flyable engines. NASA implemented the "Shooting Star" project in 1997 as a ground test system. The system was never built and the program was canceled in 1998 (NASA). However, in 1998 Boeing was awarded a U.S. Air Force contract to perform initial studies for a solar powered orbital transfer vehicle, designated "Solar Orbital Transfer Vehicle (SOTV)." The project is currently ongoing and has no flyable components yet. Currently there are no operational STREs (Boeing). Several other companies are working on STRE components.

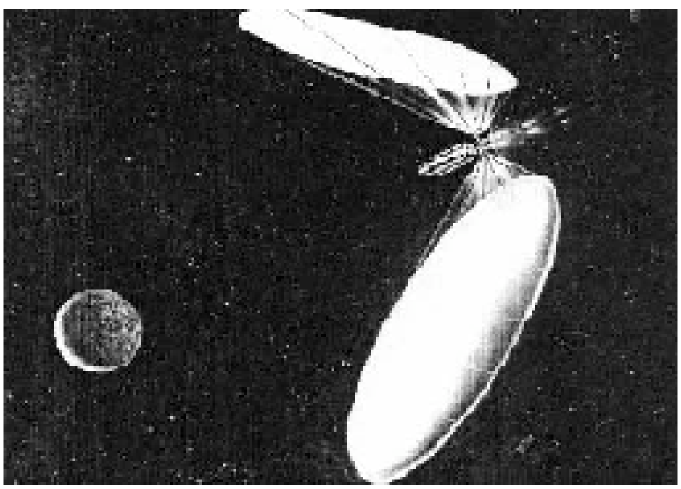


Image courtesy of Rockwell International. Image from Island One at http://www.islandone.org/APC/Beamed/03.html

Solar thermal rocket engines hold great promise for the development of near-Earth space and especially Lunar development. Their simple design, high efficiency, and safety; coupled with the possibility of the use of Lunar oxygen as the sole propellant, could reduce the high costs associated with Lunar settlement. Much basic research needs to be done to determine if STREs will have a place in space settlement. The Moon Society could be an active participant in this research.

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What a Lunar Analog Research Station Should Attempt to Demonstrate

By Peter Kokh and Moon Society Advisor David A. Dunlop

First let's clear the ground by pointing out that the goals of a Mars Analog Research Station are not necessarily the same as those of a Lunar counterpart, and vice versa. ***For Mars advocates, the goal to be defended, the feasibility to be demonstrated, is that humans and robots together can explore Mars much more effectively and thoroughly than robots alone.*** Mars advocates are trying to get the nation (and, hopefully, international partners) to commit to the manned exploration of Mars. Settlement, while a dream of most, is a goal well over the horizon.

In contrast, Lunar Advocates are operating with a given national commitment to a "permanent" manned outpost on the Moon, whatever "permanent" means.

> *We have many times pointed out that any outpost remains tentative until there is a permanent civilian population on the Moon raising its own successors, and supporting its own domestic needs as well as earning credits towards imports by products and services based on local, i.e. lunar resources.*

We have already had humans on the Moon exploring limited areas. Manned exploration is not something whose feasibility we still need to demonstrate.

Thus **our goals go beyond those of Mars advocates.**

1. We do *not* need to demonstrate the methods and tools of human-robotic exploration,
2. *We do* need to determine which operations can be done effectively by teleoperation from Earth in order to dedicate precious man-hours on location for those things that can not be done as well by teleoperation
3. We *do* need to demonstrate the methods and tools of expansion of an outpost into a settlement.
4. We *do* need to demonstrate the options for using local lunar resources to accomplish that goal.

Demonstrating Maximum Use of Teleoperations

Our long term goal is to ensure the creation of a viable lunar frontier where people of many walks of life can work, play, and raise families, supporting themselves by the production of export goods and services. To the point, there is one thing in common with all "new frontiers" in the early stages of establishment.

There is always more work to be done, than people to do it.

Our best opportunity to make sure that precious man-hours are most economically spent is to identify and demonstrate operations that can be effectively performed by personnel on Earth, "teleoperating" at far lower costs per hour. The Moon has the advantage of being only one and a fraction light-seconds from Earth, a manageable time delay.

Site preparation (grading, leveling, removal of boulders, trenching, etc.) and shielding emplacement are two obvious areas where teleoperators working on Earth should be able to get the job done, leaving crews on the Moon for other things, not so easily "farmed out." But we need to determine the best equipment to be sent to the Moon for teleoperators to control with under 3 seconds time delay.

What other operations can be so farmed out? Here lies a whole world of things that can be tested at a lunar analog station. Every operation that can be done remotely, extends the productivity of those on location that much more. Advance scout rovers could be teleoperated; mining equipment, manufacturing equipment, agricultural tasks, perhaps even road construction. Let's find out!

Demonstrate Dayspan/Nightspan Power Generation

An outpost needs power, of course, but NASA is not currently committed to demonstrating a system to store power for use during nightspan. Instead, the agency seems committed to demonstrating that the need to do so is unnecessary, because the outpost will be at the South Pole, where allegedly sunlight is available all the time.

If we are going to bring *the whole lunar globe* into the realm of a Greater Earth-Moon Economy, we have to be able to set up shop wherever resources and other assets demand that we do so, not just at one of the poles. And that means demonstrating a Dayspan/Nightspan power system. Indeed, we should demonstrate several systems, not only for backup, but so that the technology can pick the winners.

The options are several. A small nuclear power plant is, however, something totally out of reach financially for a privately supported Lunar Analog Station here on Earth. But that doesn't really matter, because outposts and settlements will come in all sizes, while "nukes" may come only in one size, and at high expense, a non versatile solution.

Hydrogen/Oxygen Systems: Fuel Cells

Excess dayspan solar power could be used to electrolyze graywater and water in reserves into hydrogen and oxygen which can be recombined in a fuel cell to produce both power and potable water. Fuel cells could also be fed by hydrogen scavenged from solar wind volatiles by heating regolith soil being moved in the process of road construction, materials processing, site grading and excavation, and import of regolith into pressurized farm areas for use as soil. Fresh oxygen can be extracted from the regolith by several well understood and demonstrated processes. Harvesting hydrogen and extracting oxygen would be dayspan activities.

Hydrogen/Silicon Systems: Silane-fueled Generators, Vehicles, and Appliances

Another entirely different possibility should be explored. Carbon is scarce on the Moon, much more so than hydrogen. Thus methane is not a fuel option. But Silane, SiH_4, a silicon analog of carbon-based methane, may be.

Silane could be called a "hydrogen extender," in as much as silicon, being much more common on the Moon than hydrogen, is used to stretch the total power output of a given amount of hydrogen. Silane has been proposed as a lunar appropriate rocket fuel.

I had some time ago asked Dr. Robert Zubrin if the adiabatic process (occurring without loss or gain of heat) to be used in making methane from the Martian atmosphere could be applied to production of silane on the Moon. He answered in the affirmative. That leaves us with the belief that this is a direction worth pursuing.

First we could demonstrate methods of producing Silane from regolith. Engineering competitions at the College- University level are an option worth pursuing. Then, by similar competitions, we could seek to demonstrate silane-fueled generators, silane-fueled vehicles, and silane-fueled appliances.

The Silane would be produced during dayspan in quantities sufficient to fuel appliances and vehicles at all times, and generators during nightspan. Silane-fueled generators could also be used at all times at small construction camps and other temporary installations where it makes no sense to deploy a large scale solar (or nuke) power system.

Continuing productivity through the nightspan by use of "change of pace" task sequencing

Few things need demonstration as much as the ability of pioneers to survive the two week long lunar night. Here on Earth, alternating fortnights of full daylight and total darkness (except for Earthlight and starlight) within a warehouse or arena with blacked out windows and total lighting control. But we can come close at an outdoor Habitation structure such as the Mars desert Research Station, by having the crew active for two weeks during local daylight hours, then shift to a schedule offset by 12 hours, awake and active only during the local Utah night. The portholes and windows could be blacked out, or uncovered, as needed to create the right atmosphere inside. Crews would go outside only during daylight, and nighttime hours alternately over a four week cycle.

We might learn more from week 1 dayspan, weeks 2 and 3 nightspan, week 4 dayspan. This way two transitions, from abundant power to rationed power, and from rationed power back to abundant power could be modeled. If we could only afford to rent the MDRS facility for two weeks, we could operate on a 4 day light, 7 day dark, 3 day light sche-dule, telescoping the lunar cycle into half the time.

In such a light/darkness regime, crew members could experiment with the management of operation tasks to suit the greater amount of power available during the two "daylight" weeks, and the lesser amount available during the two "nighttime" weeks. Various tasks could be sepa-rated or precipitated out into energy-intensive ones to be executed during the light period and energy-light and perhaps labor-intensive tasks to be taken care of during the night period. Some operations will lend themselves to such a sequential execution; others may not. It will be a learning experience.

Meanwhile, we can demonstrate power generation during the dayspan period by use of photovoltaics, and solar concentrators, and other means. During this period, excess available energy would be used to electrolyze graywater, as suggested above. For backup to fuel cells, we could develop and improve silane-fueled generators, furnaces, ranges, refrigerators, and rovers.

For more on the topic of dayspan-nightspan task sequencing, confer these back articles:

MMM #7 July, 1987 "Powerco"
- reprinted in MMM Classics #1, pp. 21-22

MMM #43,March,1991 "Dayspan," "Nightspan"
- reprinted in MMM Classics #5, pp. 10-12

MMM Classics Pdf files are freely downloadable at either:
www.lunar-reclamation.org/mmm_classics/ or:
www.moonsociety.org/publications/mmm_classics/

Modeling "Modular Biospherics"

1. Modules for expansion

Expansion of our outpost(s) is(are) can not reason-ably be supported by the prohibitively expensive import of habitat modules and connectors manufactured on Earth. With so astronomically expensive a cost pre square foot of usable space, the governing constraint will be to jam pack each unit with equipment, reducing crew quarters and recre-ation space to "sardine can" cubbyholes, and making many desirable activities much too expensive to support.

The next step would be to bring in inflatable structures packed uninflated and compacted for the ride to the Moon in constraining payload bays and farings, then finish outfitting them on location. These could be spheres, cylinders, or torus-shaped volumes. The latter provides a stable "no-roll" level footprint and the greatest volume to height ratio, making shielding easier. While inflatables designed for use in low Earth orbit must have foot-thick membranes to protect against puncture from orbital debris, inflatables designed to be covered with shielding on the Moon would need only a much thinner membrane, meaning that inflated, they could provide significantly more volume (with perhaps ten times the membrane surface area) than similar LEO-destined inflatables, when both are to be transported in the same size payload bay or faring. The real challenge of inflatables is to design interior systems that can be quickly and easily deployed, once the structure is inflated. Again, college level design competitions may prove useful in coming up with elegant solutions.

The real breakthrough, however, will be the achievement of the capacity to manufacture modules and module components locally on the Moon with made-on-Luna building materials: metal alloys, glass fiber reinforced concrete, glass-glass composites. The price of new space will be reduced drastically. The outpost will grow module by module, along with the crew - the population.

2. Making each module of the growing structure, also a Module of the growing biosphere

Meanwhile, we will have to grow the biosphere that supports the complex. The simplest and most elegant way to do this is to equip every lived-in, worked-in, played-in, learned-in module with a Wolverton* type toilet system that flushes sideways through the bathroom wall to water a row of platers beginning with water plants, swamp plants, marsh plants, bog plants and then soil plants. By the time the black water leaves the module, it is 95% pretreated, vastly reducing the load on a central water recycling system.

* To learn more about the Wolverton System, check out:
http://www.wolvertonenvironmental.com/

These "principles of modular biospherics" are something worth modeling and demonstrating at a Lunar Analog Research Station. Such a system will go well beyond whatever system NASA uses to refresh air and water in a fixed size outpost, and thus demonstrate the technologies needed for expansion of an outpost into a real settlement.

The modules would need to pipe in sunlight or alternately, banks of grow lamps. (The pathways provided for sunlight could be used by light from intensely bright external sulfur lamps during nightspan.) The plants within each module would largely refresh air within, and fill the interior with the greens of vegetation and the color of flowers: fresh air, greenery, color - not an add-on but an integrally designed feature of each module.

In such a system, the biosphere grows one module at a time. The settlement'sphysical plant does not outgrow the biosphere's capacity because the two are one and the same. Not just the major modules that comprise living, working, and recreation space, but also the connecting passageways and "streets" should do their share by hosting plant rows along their sides. We must always keep in mind that *it is not a case of humans playing host to house plants, but of vegetation playing host to humans, enabling our survival!*

We could build our Analog Station with a mix of hard hull modules, inflatable modules, and modules made of materials we should be able to process on the Moon. Perhaps the core operations would be in the hard hull starter units:

1. Crew Quarters - Library - "Quiet Spaces Module"
2. Computer workstations: communications, controls, monitors, reports, teleoperations, CapCom, Office
3. Kitchen, Pantry, Ward room, meeting space
4. Bathroom, showers, exercise/fitness area, 1st Aid
5. Lab space for geological and mineral samples
6. Utilities: power, thermal control, engineering workbench
7. Airlock and suit-up area. Dust decontamination

The above modules could be directly interconnected or connected via passageways, as the needs for isolation or of juxtaposition dictates.

This basic 7-unit complex contrasts with the all-in-one approach illustrated by FMARS and MDRS. The Lunar Analog Station, by beginning as a modular complex, would be set to grow in like fashion. Additional modules could be added for recreation and sports, arts & crafts space, and areas for experiments with processing and materials. The complex would begin to look like a self-sufficient commune.

All units would house vegetation. This would be in addition to the Greenhouse, itself modular, which could grow as success, food demand, and the desire for more variety increases. A Greenhouse area could host a picnic corner, a get away reading spot, a biocrafts area, and so on.

Thus a Lunar Analog Station would not be a weak "me too" operation, but one with rather ambitious goals that go well beyond what the Mars Society is attempting to do. It is only fair to point out, however, that The Mars Foundation is moving in that direction also. This group is attempting to identify all the technologies needed to transition an outpost into a permanent settlement on Mars, and dreams of building a prototype Mars settlement somewhere on Earth.

Other things worth demonstrating at a Lunar Analog Research Station

1. Teleoperable shielding emplacement systems
2. Erection of shielded hangers within which to indirectly shield pressurized modules and/or to house supplies and systems that need to be accessed on a regular basis
3. Greenhouse systems
4. Early industries: cast basalt, glass, fiberglass, glass composite, concrete, metal alloys
5. Art media using only lunar producible materials
6. Refurnish the Habitat with objects made in the above demonstrations. And on and on.

Evolution of the Analog Complex with regular "Updating Makeovers" as new technologies are demonstrated

Of necessity, the initial complex modules will be built with available terrestrial materials. However, right from the outset, floors could be finished with cast basalt tiles made in Czechoslovakia and marketed in the US out of West Virginia. We could also start out with interior walls constructed not of 2"x4" wood studs and drywall (as is the case at MDRS and FMARS), but of steel studs and *duroc* cement board. Not only would that be closer to what we might end up doing on the Moon, it would be a fireproof solution.

As we demonstrate new materials technologies, we could then replace more and more of the original materials, furniture and furnishings used in the station with those analogous to what we might be able to produce on the Moon. In this manner, the quality of the "simulation" would keep increasing - proof that we *are* learning things worthwhile!

A Lunar Analog Station as a Part of a larger Project

A Lunar Analog Research Station is but one part of a grander dream of the Moon Society, called Project LETO {Lunar Exploration and Tourist Organization] which would involve a major tourist and educational center. It is my opinion that the research facility should not be included in such a complex but located separately in an appropriate isolated landscape. However, a twin facility at the tourist center, evolving (expanding and upgrading) in step, would be available for regular tours. It would have monitors at each location to show web cam views of what is currently going on in the real research station.

The Mars Society relies on publicity for its analog stations to increase public support and funding. But a sister complex open to tours with a peep hole into the actual one, if located in a high tourist traffic area such as Las Vegas or Orlando, would greatly increase public exposure, public enthusiasm, and, equally if not as important, a steady flow of donations and new members.

What's Next for the Moon Society–NSS collaboration? Another Crew at MDRS? Moving somewhere else?

We can do *some* of these things suggested above at the Mars Desert Research Station in the 2007 Field Season - for example, a 1st modeling of operations through a complete lunar dayspan/nightspan cycle.

However, demonstration of a modular bio-spherics expansion architecture, as it involves the facilities themselves, would necessitate an independent operation on a separate site. It would be foolish to make major capital investments in a facility not our own, and from which we planned to move. Further, there is no reason to believe that the Mars Society would approve any such expansion plans. If we want to do these things, we must find another site and deploy a fresh habitat complex of a friendlier design.

As for a new site for our new modular complex, locating it in a "lava sheet, lava tube area" would be optimum for silane and/or fuel cell based utilities, cast basalt operations and other materials processing and manufacturing operations we want to demonstrate. It will take some time both to identify a new site and acquire access and use.

It would take more time, and money, to deploy our desired complex. However, we could start with a mockup complex of rented or purchased used old camping trailers, replacing them one at a time with new construction. This is a plan that would involve the minimum interruption in annual simulation exercises, a plan that would maintain momentum.

2006 -plan a 2nd crew to MDRS in the 2007 field season
2006-2007 locate and acquire access to a new site in a geologically more appropriate area
2007 - 2nd exercise at MDRS
2008 - 1st exercise at new Lunar Station with temporary camper modules or RVs
2009 - replace first camper with permanent module, etc.

We can do this! But not without donations! We are still $1250 shy of full funding for this year's effort! *To find out how to donate, write kokhmmm@aol.com or write us at the MMM submission address, on page 1.* **<MMM>**

The Mars Analog Research Station Program is Missing Key Critical Opportunities.

Central to the Mission Plan of "Mars Direct" is the thesis that we can make fuel for the return to Earth leg of a Mars exploration mission on Mars itself. By not having to lug along return fuel to Mars, an outbound Mission can be significantly lighter, which translates to significant savings. A "Mars Direct" mission would cost only a fraction of a traditional mission architecture.

The return fuel, to be derived from Mars atmosphere, is methane, CH_4, which would be burned with oxygen, also extracted from the atmosphere. The idea is brilliant and elegant: a natural solution.

Why then are we operating the generators at FMARS on Devon Island and at MDRS in Utah on diesel fuel? Why are we operating the furnace, the range, and the refrigerator with propane? Granted, these are the kinds of equipment available now for powering a station on Earth "off the grid." What we do not understand is why there is no engineering competition to develop methane fueled generators, furnaces, ranges, and refrigerators. Wouldn't such a demonstration go a long way to show the world that the "Mars Direct" plan will work? Wouldn't that show skeptics that an outpost on Mars is feasible?

How difficult would it be to develop methane-fueled vehicles, appliances and generators?

It shouldn't be that difficult considering that there are already more than a million vehicles worldwide, mostly buses, fueled by natural gas. And natural gas appli-ances are commonplace. After all, natural gas is 90% methane. We simply need to try using a 100% methane fuel.

An alternative would be to demonstrate the production of propane C_2H_8, a proven fuel, from the Martian atmosphere, taking methane CH_4 production one step further.

Perhaps there is indeed a long range plan to do this, but if not, it is time for the Mars Society to up the ante, go to the next step: demonstrate these critical technologies.

While they are at it, at leas one rover at one of the analog stations should be methane- or propane-fueled. As it may be impractical to convert ATVs that the Society is only renting, this demonstration vehicle could be a "pressureized rover" - perhaps the vehicle that brings in (and takes back) crew and supplies from staging points in Salt Lake City or Grand Junction, CO..

We can think of more things that could be done at FMARS and MDRS - (the 3 minute response delay should be varied within a 6-40 minute range to be realistic) - but we'll leave it like this for now. **<MMM>**

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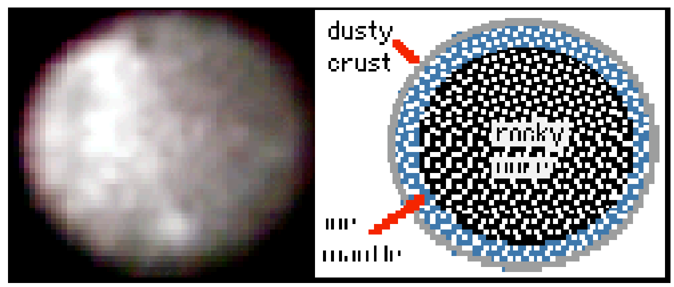


Ceres - biggest asteroid or "embryonic-planet?"

New observations of Ceres, the first, and by far the largest, asteroid ever to be discovered, suggest a rocky core surrounded by a substantial water-ice mantle and a thin dusty crust. These are resources that, if properly developed, could make Ceres not only the gateway to the asteroid belt, but perhaps the gateway to the entire outer solar system. See *below* for more facts and possibilities.

Scientific-Industrial Utilization of the "Lunar-Unique" Environment

- **high vacuum** (vastly cleaner and higher than in LEO)
- **no global magnetic field** (unlike in LEO)
- **fractional gravity** (mechanical advantage over LEO's 0-g)
- **minimum atmospheric activity** (levitated dust at dawn)
- **seismically stable** geological structure
- **sterile environment** (no air, water, soil pollution)
- **slow rotation** once every 29.5 Earth days
- **minimal seasonal thermal variation** (3° F/C?)
- **no humidity/water vapor**

The challenge is to identify scientific, chemical, and industrial processes that one or more of these unique environmental characteristics makes practical or possible on the Moon that are impractical if not impossible here on

Earth or in Low Earth Orbit (i.e. at ISS or other future orbiting laboratories or factories).

Yes, you've heard a similar question posed before: what can we do in the micro-gravity of Earth orbit that we cannot do here on Earth's surface? We have yet to find potentially *profitable and practical* applications for proces-sing and manufacturing at "zero-g" ("micro-g" may be more *picky*-accurate) in space stations and orbiting factories. But that should not discourage us from looking for similar advantages that the Moon's unique environment may offer.

That LEO offers zero-g and the Moon only 1/6th gravity is not grounds for dismissal. "Fractional gravity" may preclude some chemical processes but it confers a very real mechanical advantage to material handling and other mechanical opetatins. And the Moon offers advantages that LEO or other orbital locations do not:

The vacuum above the surface layer that is periodically "spoiled" by levitated electrostatic dust at dawn is much cleaner than the permanently dust and debris ridden low Earth orbit area, simply because that light one-sixth gravity continually purges that vacuum of foreign material including corrosive free oxygen.

LEO is very much affected by Earth's global magnetic field. The Moon, lacking such a field, has the advantage whenever background magnetism can affect a chemical or physical reaction negatively.

The Moon supplies an extensive seismically quiet (in comparison to Earth) platform for use of **global telescope arrays**. The only disturbances come from impacts, not tectonic plates in movement. Are there other advantages to this seismic quiet that may benefit research or industry?

That the payoff is yet to come from the so-called advantages of "doing it in Earth orbit" should not dissuade us from looking for possible processes and research that are uniquely favored by the special combination of scientific environmental assets given above to "doing it on the Moon."

If there are no areas of industrial and scientific activities better suited to the Moon than to either Earth or Mars, that would be surprising. The payoff to those advan-tages we find and are able to leverage could make minor contributions to the economic viability of lunar settlement. But until we find out otherwise, we cannot rule out the possibility that the payoff could be economically significant.

This line of research is certainly worth pursuing, and some of this research may not need to wait until we find ourselves on the Moon with adequate laboratories and other facilities. The issues are technical, however, and it is for specialists in each of the many areas of science and indus-try to identify operations that would benefit form the "Lunar-Unique" environment.

If lunar settlement and industrialization is to be viable, every area of possible advantage must be explored and pushed to the limit.

Some likely applications:

Biology

- Quarantine Lab for Mars Sample Returns, Europa Sample Returns

Astronomy

- Radio and Optical Telescope Arrays (interferometers)
- Northern and Southern hemisphere telescopes that can be set on a given stellar object 24/7/365 (vs. a fraction of each day for only a part of the year)
- Very large Arecibo-type radio dishes in craters, of which many thousands would be suitable

Energy

- Solar power arrays

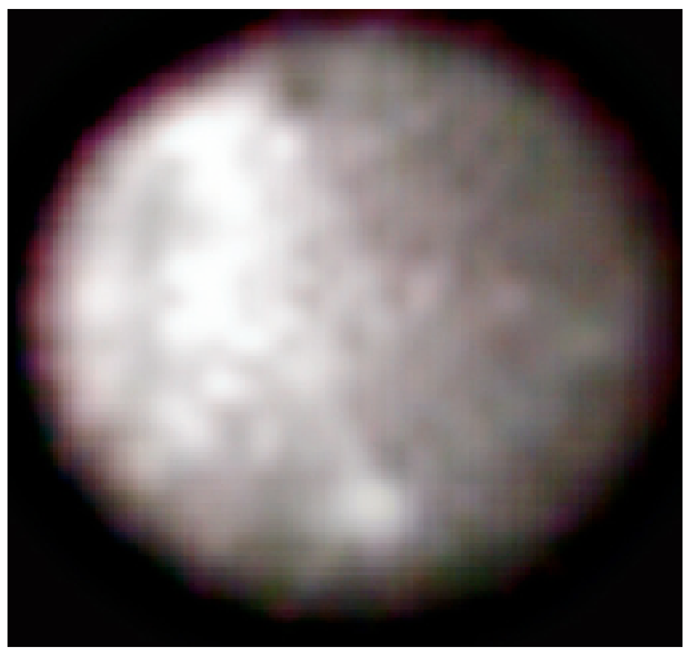
Architecture/Construction

- Very tall towers are possible, kilometers high, for observation, relays, cable & cableway suspension, etc.
- Extensive use of Magnesium and ironfor surface construction it (both would quickly oxidize on Earth)

CERES

Ceres – *Largest* Asteroid? or *Mini*–Planet?

Peter Kokh, David A. Dunlop, David Dietzler



This contrast-enhanced false-color composite of Ceres is made from Hubble Space Telescope visible and ultraviolet images. http://www.astronomy.com/asy/default.aspx?c=a&id=3478

Relevant Reading from Past Issues of MMM

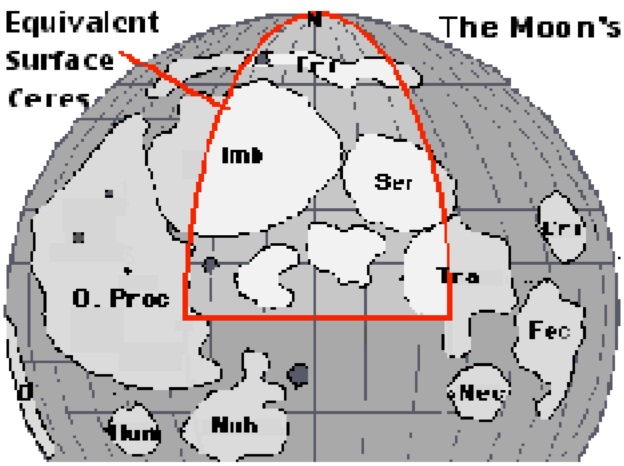
MMM #24 April '89, "Ceres, Pallas, Vesta" pp. 4-6
republished in MMM Classics #3, pp. 23-24
www.lunar-reclamation.org/mmm_classics/mmmc3_Jan2005.pdf
MMM #70 Nov. '93, "Asteroid Workshop, Part I, A Permanent Main Belt Service Center on Ceres, pp. 3-8
republished in MMM Classics #7, pp 62-66.
www.lunar-reclamation.org/mmm_classics/mmmc7_Jan2006.pdf

Sizing Up Ceres

DIAMETER: equator: ~975 km (~606 mi); polar: ~909 km (~565 mi); mean: ~950 km (~590 mi)

SURFACE AREA: 3,160,000 km2 (1,219,000 mi2)* [*based omn former diameter estimate of 1003 km]

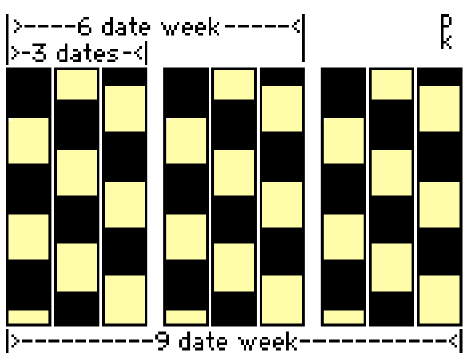
COMPARABLE TO:
= All of India (1,229,737 sq.mi.)
= 40% of the Continental U.S.= either east or west of the plains states (i.e. excluding North Dakota thru Texas)
= Queensland plus Northern Territory in Australia
= A slice of the Moon from the Moon's N pole to its Equator, and from 27 °Wto 27 °E:



CLASS AND COMPOSITION: Carbonaceous chondrite. Stony (silicates and metal oxides) with admixed water ice and hydrates.

ROTATION PERIOD (one sol): 9.08 hrs.

POSSIBLE TIMEKEEPING SYSTEMS: a 2-date cycle of 5 periods would yield dates 22 hours 42 minutes long. ***A 3-Date cycle of 8 periods = 24 hrs 12.8 min per Date***



GRAVITY: 19% Moon's, 8.31% Mars', 3% Earth's. That *might or might not be just enough* to make gravity-dependent body functions work without providing an artificial gravity environment.

DISTANCE FROM SUN: 381-447 million km = 237-278 million mi. = 2.55-2.99 A.U. 1 A.U. or astronomical unit = the Earth's average distance from the Sun. At this distance, Sunlight at Ceres ranges between 15.4% and 11% of that reaching Earth, per square meter.

To do the same job, as a solar collector 1 meter on a side on Earth, you would need a collector 3 meters on a side on Ceres. ***That is still doable.***

DAWN: NASA's Mission to Vesta and Ceres
http://dawn.jpl.nasa.gov/mission/index.asp

Mission reinstated, March 27, 2006
http://www.nasa.gov/home/hqnews/2006/mar/HQ_06108_Dawn_reinstates.html

Dawn's Early Light online newsletter (html or pdf)
http://dawn.jpl.nasa.gov/DawnMedia/index.asp

First purely scientific NASA solar electric mission
Dates: Launch June or July 2007 on a Delta 7925H
Vesta encounter 2011, orbiting Vesta for 7 months,
Ceres encounter 2015, orbiting Ceres indefinitely

Craft 90% assembled at Orbital Sciences

The occasion for this brainstorming article is the recent announcement that Ceres may have a water-rich mantle.
http://www.astronomy.com/asy/default.aspx?c=a&id=3478e

Commentary Continues

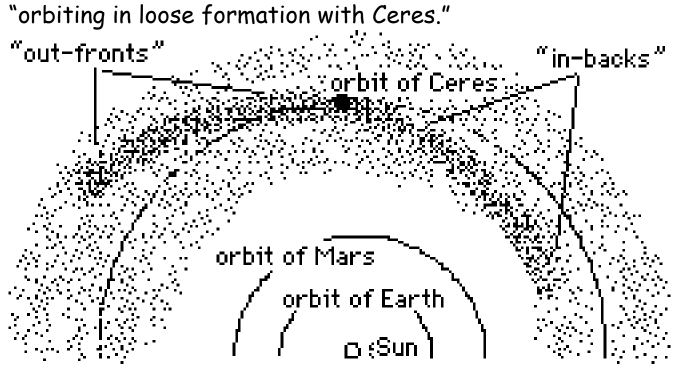
We have always known that Ceres was by far the largest asteroid. Now we realize that in resources as well as size and location, it may be the best-endowed. As such, it is sure to play a major role in humanity's expansion beyond the orbit of Mars. Our aim is to sketch the possibilities.

A Supply and Staging Center for Belt Operations: Should it be Mars or Ceres?

The Catch-22 of orbital mechanics, something that is commonly ignored, is that the closer two bodies are in orbital period, the less frequent, on the average, are the launch windows between them in either direction. That Mars is closer to the Belt is a liability, not an asset. In fact, the Moon is the better choice with much more frequent windows to most of the asteroids.

Ceres and its "Flock"

While the Moon may be the jumping off point for asteroid belt operations early on, in time, facilities at Ceres could grow to become the center of operations within a much as a third of the Belt, especially for asteroids "orbiting in loose formation with Ceres."



Ceres' orbit within the Main Asteroid Belt and the swath, in relationship to Ceres' position, in which we'll find asteroids that will orbit in formation with Ceres for many decades.

Ceres' "Service Area"
If the stats for the first hundreds asteroids to be discovered are typical, *44% have orbital periods within*

10% of Ceres' so that one third of these or almost 15% of all asteroids would be within 60 degrees of Ceres at any given time and remain there for fifteen years or longer before drifting out of range. Some asteroids will 'fly in formation' with Ceres for centuries.

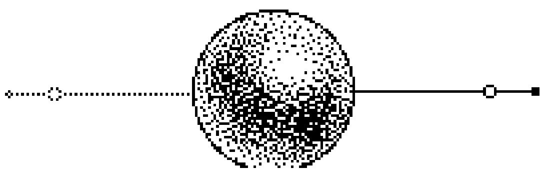
Two target groups emerge:

• **'out-fronts'** ahead of Ceres but in slower, larger orbits

• **'in-backs'** behind Ceres but in faster smaller orbits.

At any rate access to 15% of the Belt should do us well for quite a while. Between Ceres and loosely co-orbiting asteroids, craft could come and go at most any time with the only the trade off between speed and most economical use of fuel being the only real variable. As most of these trajectories will not be very eccentric, speed will be a minimal factor.

Ceres has a close in synchronous orbit just 782 km or 486 miles above the surface. Given Ceres low 3% Earth-normal gravity, an Elevator-tethered Synchronous orbit Outpost Terminal in the form of a Torus or Cylinder is much more feasible around Ceres that around Earth or Mars. (It is not possible for the Moon at all!)



Distance *to scale* of an orbital "Sync Port" above Ceres' surface, showing the elevator/tether and counterweight. Many of Ceres' port functions could be more efficiently conducted at Sync Port. The materials needed to build such an elevator are not only much less in total mass (than for Earth or Mars) but also much less demanding in performance parameters. Such an elevator could be built with today's technology.

Facilities on Ceres itself

In time, engineering development for belt needed equipment (prospector ships and tools, mining equipment, mass drivers, smelting equipment) could switch from the Moon to this regional center. Experience gained on this colder, wetter world could prove useful for ventures beyond the Belt. While mining, processing, and manufacturing facilities would be on Ceres' surface, the actual Port of Ceres spaceport could be better located in the close in synchronous orbit, with freight elevators carrying goods (and people) between "SynchPort" and the surface.

At the Asteroid Workshop in Huntsville during ISDC 1993, we spent some time better defining which functions the Ceres Settlement* would fill, and of these, which were appropriate for Ceres' low mini-gravity, which would be better placed in a surface artificial gravity environment, and which would best be filled in an elevator and pipeline cluster tethered synchronously orbiting space facility, the Sync Port", 486 miles above the main Surface Settlement.

ORBITAL SYNC PORT

- **Solar Energy facility** if practical, cabled to surface
- **Main Port of Call** for ships to and from other asteroid belt locations elsewhere in the solar system
- **Fuel Depot** for visiting ships
- **Light processing, manufacturing** incoming resources
- **Warehouse** for goods being transshipped
- **Traders' Market** for ships in port
- **Repair, maintenance, reoutfitting shops** for work that is routine, frequent, and requiring a low mass of equipment
- **Assay office** for incoming mining samples
- **Hotel** for more transient spacer use
- **Gym** for visiting personnel
- **Other recreation facilities** for transient spacers
- **Administrative offices** for handling routine matters for visiting spacers
- **Medical Outpatient Clinic** for visiting spacers
- **Other functions** for personnel, ships, goods in transit

SURFACE, FIXED (within/without main settlement area)

- **Mining and processing** of local Cerian resources
- **Manufacturing** based on local Cerian resources
- **Refinery** for fuels, volatiles from local resources
- **Custom manufacturing** using imported resources
- **Warehousing** for all of the above
- **R&D facilities** and labs for processing, manufacturing
- **Repair, maintenance, reoutfitting shops** for work needing heavier equipment that is less routine and/or frequent
- **Main agricultural areas**: food for local consumption and for export to other Belt markets
- **Nature parks**
- **Gym** using heavy equipment or for exercises that are not gravity-dependent
- **Space port** for orbit to surface shuttles loads too big or massive for the elevator
- **Main, permanent Trade Center**
- **Nuclear Fusion** (He-3) Plant
- **Main Hospital**

SURFACE, GRAVID - Artificial gravity via Maypole and/or Maglev facility

- **Residential area** (all locals to spend some time here)
- **Schools** (concern for children in developmental years)
- **Offices** (commercial, administrative)
- **Gym** for gravity-assisted exercise and sports requiring lightweight equipment
- **Hospital recovery** and rehabilitation areas
- Other activities and functions that require little space and little supporting equipment mass

What we "knew" and now "know" about Ceres

www.planetary.org/explore/topics/asteroids_and_comets/ceres.html

Ceres is estimated to contain one quarter of all the mass in the asteroid belt and it had been clear from its crudely calculated density and spectrum (carbonaceous chondrite) that it must contain a good percentage of the water-ice in the Belt. We thought that this resource might be just mixed in with the rock, but we now believe that Ceres may contain a mini subsurface ocean, similar to that on Europa, but on a much smaller scale.

Ceres suddenly emerges as a much more complex and interesting "little planet" all by itself, not only the largest of the asteroids, but in a whole league all by itself. Ceres becomes not just an asteroid, but the place to visit and do business in the Belt.

If we were to abandon our fixation with size is everything in deciding what is a planet and what is not, and look at the object's potential to have a roll in the spread of humanity, Ceres might be given the appellation "planet." Maybe we need a new word, not laden with size connotations, for objects that will play a major role as a human pioneer frontier of the future. Don't bother to look in a thesaurus. It is of little help. We'll just have to coin something. After all, Europa too needs to be reclassified! Whether a body orbits the Sun directly or indirectly seems irrelevant!

The Outlook for Ceres: Phase I:

a. In time, engineering development for belt needed equip ment (prospector ships and tools, mining equipment, mass drivers, smelting equipment) could switch from the Moon to this Belt regional center.

b. The presence of considerable amounts of water ice and or ice/rock mixture along with this planetoid's carbonaceous crust means that **Ceres could be biospherically self-supporting** in food, fabrics, plastics, fuels.

c. Ceres could become the principal center in the Solar System for the **development of cryoplastics** including building materials that perform well at cryo-temperatures. (-100 to -200 °F ?) This industrial activity would enable opening frontiers further from the sun.

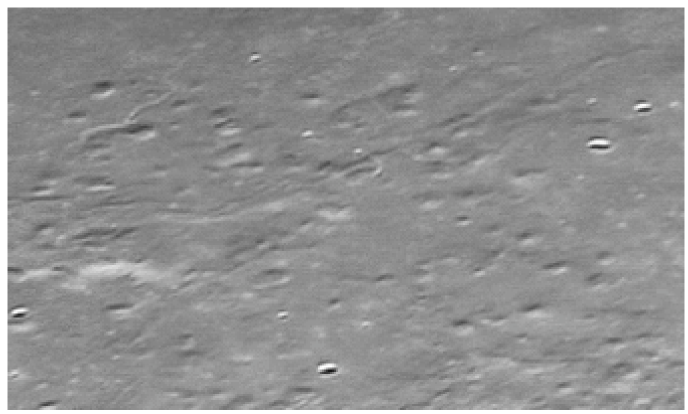
Phase II:

Given these advantages, Ceres seems destined to become a principal **staging point for exploratory expeditions, outposts, and settlements in the Jovian and Saturnian systems and beyond.** Some writers had previously expected that Callisto, the only one of Jupiter's big four Galilean satellites that is outside Jupiter's radiation belt, would emerge as the gateway to the entire outer system. But Callisto's sphere of influence might be confined to the Jovian system alone, with Ceres having more frequent launch windows to Saturn, Uranus, and Neptune.

Ceres would grow in population and wealth with the spread of asteroid activities (phase 1) and then with the spread of asteroid activities (phase 1) and then with the opening of the Jovian Moons (phase II). The limiting factor is the size to which its "SynchPort" could grow at the end of a tether. I'll leave it to science fiction writers to propose a vast "Synch Ring World" above Ceres, some 5,000 miles in circumference, or how artificial gravity would be maintained within it (perhaps this "ring" would be of individually rotating "sausage link cylinders" of the O'Neill variety, with lunar gravity (that of Io, Europa, Ganymede, Callisto, and Titan are similar) as the likely standard beyond Earth. A short pool of suitable place names for Ceres.

Giuseppe **Piaszzi** discovered Ceres in **Palermo**, **Sicily** on the first day of **Century Nineteen** - 01-01-1801. Ceres was the Roman goddess of grain [hence our word "**cereal**"], and she chose the mortal **Triptolemus** to carry her knowledge (the plow, **agriculture**) to humanity. The **Ambarvalia** were rites of spring celebrated by Roman farmers in Ceres' honor. **Demeter** was the Greek equivalent of Roman Ceres.

My pick? The Century Nineteen Hotel in New Palermo; The Ambarvalia annual festivals; The Triptolemus subsurface ocean. But I won't be there to do the honors. Other names, of course, will be conferred by explorers and settlers in honor of places and persons whom they wish to remember, persons in places in their favorite works of fiction, etc. as has always been common and traditional among settlers and pioneers.



The Marius Hills

LPOD: Lunar Photo of the Day

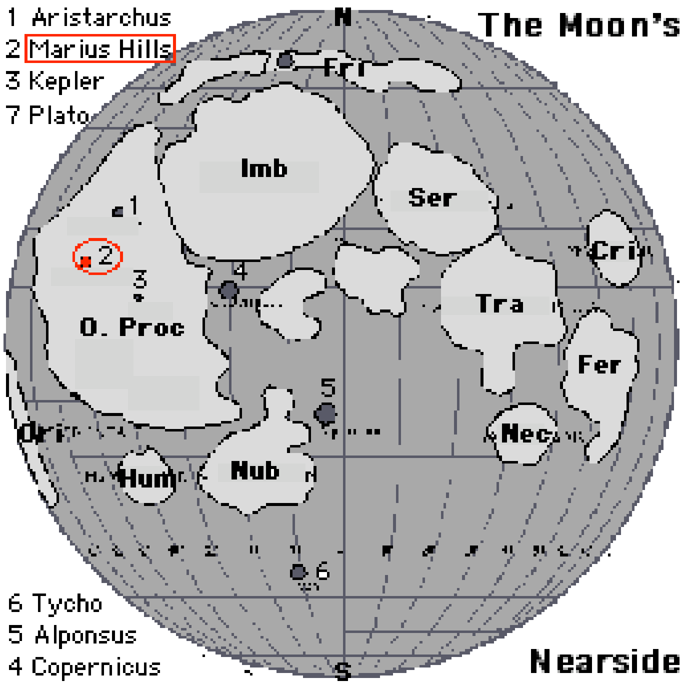
January 21, 2006 (portion of photo) This is the largest volcanic complex on the Moon (neglecting all the maria, of course) and no one understands why it exists. It appears that the entire area may be slightly higher than the surroundings, like a miniature ... of the Aristarchus Plateau. The Marius Hills includes hundred of slightly steep hills and flat domes and three sinuous rilles.

Spectral studies show that the steep hills have volcanic ash on them, indicating that explosive eruptions built them. The domes were formed by non-explosive flows of lava. And the sinuous rilles probably formed from greater rates of flow of lavas. -- Charles Wood [1]

Could the Originally Intended Landing Site for Apollo 17 have Changed History? It may change the Future!

By Peter Kokh and David Dietzler

Marius Hills (14°N, 56°W)



What has intrigued us (P. Kokh & D. Dietzler) is the suspicion that the Marius Hills might someday be the Ruhr of the Moon, (its major industrial complex) and make an outstanding site for a major settlement. **The Hills offer:**

- variations in basalt
- perhaps a good number of intact lavatubes
- possible or likely pockets of unreleased volcanic volatiles that could change the prognosis for industrial development of the Moon.

This area appears to have experienced a number of. lava/magma flows, each successive flow somewhat different. chemically than the one before - "layered igneous intrusions". in geological parlance. On Earth, the most significant case is. The Bushveld area in South Africa, source of much of that country's mineral wealth. The reserves of chromium, platinum, palladium, osmium, iridium, rhodium and ruthenium. are the world's largest along with vast quantities of iron,. tin, titanium and vanadium. [2] South Africa is second only. to the United States in the production of mineral resources..

The elements listed above are essential to a modern. industrial complex. If the Lunar Frontier were to rely only. on the elements most abundant on the Moon, oxygen, silicon, iron, aluminum, titanium, magnesium, and calcium, the result. would be something like late nineteenth century industry, more than an advanced New Stone Age" but not much more..

Lunar industry must find, or import at great. expense, copper, gold, silver, platinum, zinc, lead, and other. metals not well represented in the regolith at large. The. Clementine and Lunar Prospector data have yielded helpful. maps, but their resolution leaves much to be desired. New. orbiters with more sensitive instruments able to detect. specific signatures at very high resolution are essential.. Prospecting from orbit is extremely cheap in comparison to. fielding and supporting a veritable army of human prospectors. on the ground! The later will be needed in time, but. they are best used in areas targeted for further "ground. truth" investigation by orbiting chemical sleuths..

Clementine, Lunar Prospector, and Truth in Science

Clementine, Lunar Prospector, and Truth in Science Clementine and Lunar Prospector have clearly shown that the Nearside Mareplex is much richer in iron, titanium, thorium and other useful elements than highland sites. The poles, in contrast, have little of industrial significance beyond the yet to be "ground truth" qualified and quantified hydrogen enriched permashade areas, and more round-the-month low angle sunlight in mountainous terrain that may be risky to traverse (ever-changing very long ink black shadows as well as anything but level) with irregular plateaus of "eternal sunrise" (To use the term "eternal sunshine" is very misleading.) At the poles we may find water ice of yet unknown purity and mixture with regolith, and of yet unknown friendliness to mining techniques, and nothing to do with it except waste it as one-time-use rocket fuel.

But these same Clementine & Lunar Prospector maps do not tell us where the real prizes are to be found, if anywhere. But looking at topographical and geological characteristics, the Marius Hills area certainly looks intriguing, perhaps even promising.

Questions and more questions

David writes: study of the impact craters in the region revealed none that had penetrated through to the underlying highland bedrock. So if there are underground chambers, "vesicles," of volcanic gas, they might be intact.

So much for the "Moon is all homogenized, contains no surprises, the crust is all fractured, gas would have all leaked out" theory that I have come to believe is entirely false. I say this region could be like a volcanic gas field, truly a gold mine for lunans. One can see that there are no giant craters there or fissures in the surface."

Peter: I checked the reports on TLP, transient lunar phenomena which might include leaking gas. This does not seem to be a "TLP area," unlike the nearby Aristarchus Plateau, which is the source of many TLP reports. But the major difference is that in the Aristarchus Plateau, we have a major relatively recent impact crater, Aristarchus itself, which has clearly penetrated into the highland crust underlying the basalt flows which formed the plateau.

David: clearly any gas in fractured basalt has already long escaped. I am growing confident that there may be intact pockets of volcanic volatiles in unfractured layers. Ground penetrating radar and landing teams with explosives and sonic sensors like the stuff they use for oil exploration are what we need. What we have to do is create a vision for others to be inspired by.

Volcanic Gases? The Envelope, Please!

On Earth, more than molten rock, thick fire-red lava escapes from the throats of active volcanoes! See: http://volcanoes.usgs.gov/Hazards/What/VolGas/volgas.html

"At high pressures deep beneath the earth's surface, volcanic gases are dissolved in molten rock. But as magma rises toward the surface where the pressure is lower, gases held in the melt begin to form tiny bubbles. The increasing volume taken up by gas bubbles makes the magma less dense than the surrounding rock, which may allow the magma to continue its upward journey. Closer to the surface, the bubbles increase in number and size so that the gas volume may exceed the melt volume in the magma, thus creating a magma foam. The rapidly expanding gas bubbles of the foam can lead to explosive eruptions in which the melt is fragmented into pieces of volcanic rock, known as tephra. If the molten rock is not fragmented by explosive activity, a lava flow will be generated."

"The most abundant gas typically released into the atmosphere from volcanic systems is water vapor (H_2O), followed by carbon dioxide (CO_2) and sulfur dioxide (SO_2). Volcanoes also release smaller amounts of others gases, including hydrogen sulfide (H_2S), hydrogen (H_2), carbon monoxide (CO), hydrogen chloride (HCL), hydrogen fluoride (HF), and helium (He)."

Now given that the Moon was apparently formed from material from which any native volatiles had been driven off by heat, we will be most unlikely to find water or water vapor or hydrogen, either alone or in combination.

The Moon is also apparently "underoxidized." Even though the regolith and the crust from which it is derived by impact gardening is 45% or so oxygen by weight, in the form of metal oxides and silicates, there is not enough oxygen to have rendered the vast majority of the Moon's crustal iron into the ferric form, Fe_2O_3 predominant on Earth. The iron we find is predominantly ferrous, FeO, or even pure, not oxidized at all. That leads us to suspect that the fully oxidized forms of carbon and sulfur are also unlikely. Instead of carbon dioxide, we will be lucky to find carbon monoxide. Instead of sulfur dioxide, we will be lucky to find sulfur monoxide. Helium is also unlikely.

As there is enough sulfur, and enough oxygen in the regolith, the presence of SO gas is of no interest. The prize, perhaps the sole prize, as we see it, is pockets of carbon monoxide, CO, which would be most invaluable, both as a handy industrial reagent in itself, and as a source of carbon which is vital to life in all forms, as well as essential in making steel. We may never find enough carbon on the Moon to use profligately in plastics and other synthetics.

Gas pockets may be too small and insignificant in volume to show up as "negative mascons", even at highest resolution. Radar designed to ferret out lavatubes might find such pockets. They would have characteristic shapes noticeably different from the long tubular lavatubes.

The discovery of substantial carbon monoxide reservoirs on the Moon would rival the discovery of polar permashade ice reserves in brightening the prospects for fuller industrial diversification, and the chances of attaining economic self-sufficiency. We had previously considered the possibility of finding such "lacunae" (to suggest a Latin topographic term) but The Marius Hills are the first site to suggest that "here is a good place to look."

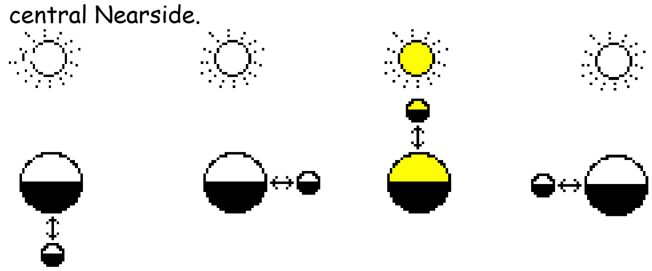
We have a lot of prospecting homework to do on the Moon before we can be confident that any reestablished human presence on the Moon has a real chance of an open-ended future. Most lunar probes are designed by scientists with things on their minds other than resources. Scratching the itches of scientific curiosity is good. But it is not what we need. This should guide what missions we support. MMM

Trick Lunar Trivia Question:
When is the Moon closer to the Sun? During Dayspan or during Nightspan?

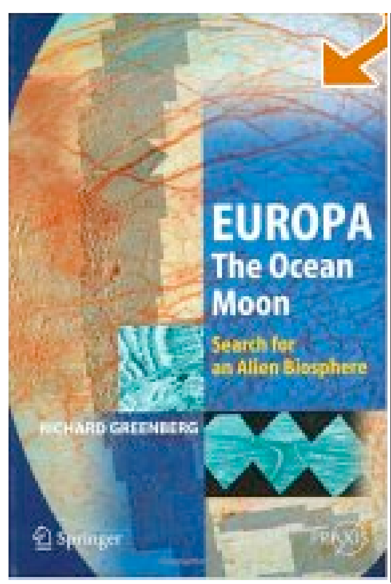
A. The Moon in general is closer to the Sun at New Moon than at Full Moon. That means during Dayspan on the Farside and Nightspan on the Nearside.

While Earth's orbit takes both Earth and Moon closer to and further from the Sun during the year, season for season, the Moon is closest to the Sun when it is between Earth and the Sun, at "New Moon," and overhead on Earth at noon, rather than at midnight.

Thus "high noon" on central Farside will be somewhat hotter, season for season, than "high noon" on central Nearside.



New Earth Full Moon | 1st Half Earth 2nd half Moon | Full Earth New Moon | 2nd half Earth 1st half Earth



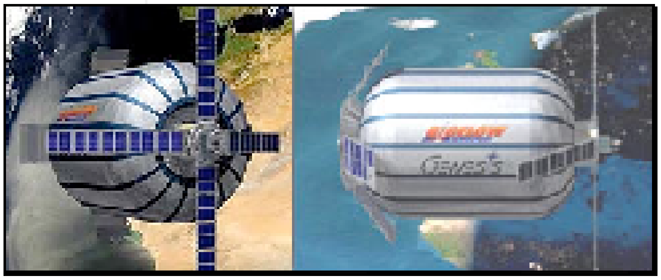
EUROPA:

The Ocean Moon
Search for an Allien Biosphere

by Richard Greenberg

Springer, 2005
ISBN: 3540224505
Hardcover 380 pages
Table of contents on Amazon.com at:
http://www.amazon.com/gp/product/3540224505/102-2140818-7585705

MMM #197 - AUG 2006



July 13, 2006 – First Inflatable Module in Orbit!

After a flawless launch in the nose faring of a Dnepr rocket, Bigelow Aerospace' Genesis 1, 1/3 scale proto-type of the 22ft by 45ft full scale Nautilis inflatable habitat module, successfully entered orbit and inflated. Genesis will be monitored for how well its envelope performs. This technology may lead to more spacious and less expensive space stations, orbital hotels, and lunar outposts*! below.*

INFLATABLE HABITATS

A Promising Technology at the Threshold

By Peter Kokh

Background: Late 1990's to present

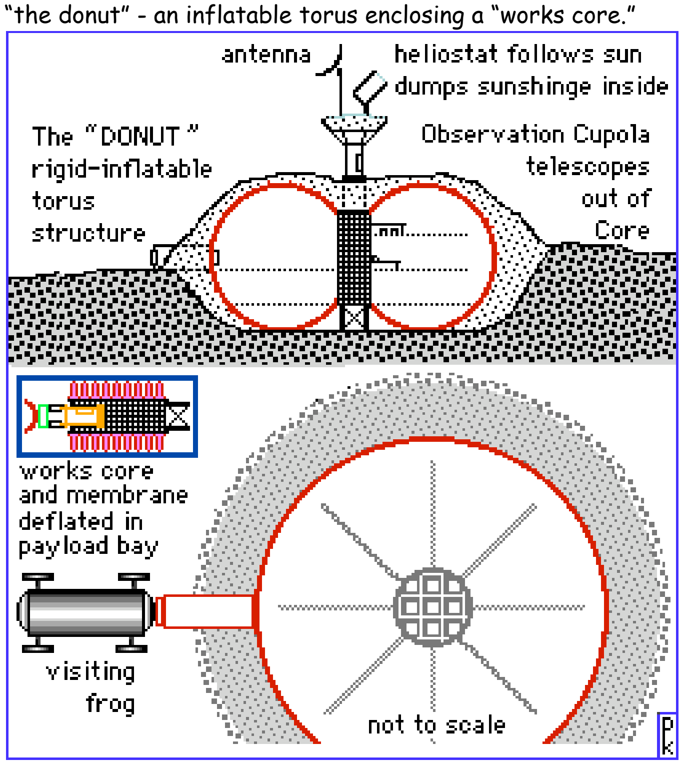
In the late 1990s, a NASA team under Donna Fender was developing inflatable habitat technology in the TransHab program at JSC. I visited the TransHab work site while at the 1999 ISDC in Houston. It was an exciting project for all of us. But three forces worked together to cancel this program. Congressman James F. Sensenbrenner (R-WI) worried that successful completion of this project might lead NASA to scuttle its hard hull Space Station Habitat in TransHab's favor, and that such a development might give those Europeans opposed to ESA involvement in the Space Station (he specifically mentioned unnamed French and Germans ISS program opponents) the opportunity they needed to opt out of the program. He told me so in person at a meeting I had arranged with him in August 1999 at the request of Mars Society founder Robert Zubrin. Zubrin saw TransHab as an inexpensive Mars Expedition living quarters option in lieu of the hard hull "double tuna can" design modeled by the Mars Arctic and Mars Desert Research Stations in Canada and Utah.

But others in Congress also wanted to kill TransHab as a cost-cutting measure. Finally, the Space Frontier Foundation wanted NASA out of the inflatable technology development business to clear the way for entrepreneurial development of this technology. *It is now quite clear that the Foundation was right on target.* The lesson? The fastest way is not always the best way!

The NASA Authorization Act of 2000 (H.R. 1654), Section 127. It prohibited NASA from developing its own inflatable module but specifically allowed it to procure one commercially. Subsequently, a memorandum of Agreement was signed between Boeing, SpaceHab, DASA, Alenia-Spazio, and Bigelow Aerospace to develop a joint business plan to bid on a commercial version of the TransHab. Bigelow emerged as the sole winner of this "competition" and secured the license to further develop the technology from the point to which NASA had brought it.

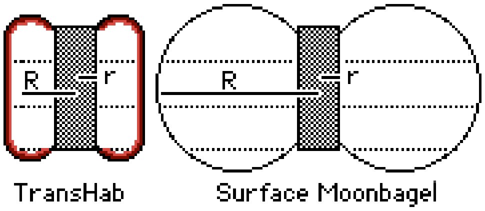
Background: before TransHab

NASA's TransHab project was not the beginning of the story. Others had proposed inflatable structures as the best way to get more habitat volume at less weight and less money given the constraints of payload bay and rocket faring size constraints. Lowell Wood of Lawrence Livermore National Lab had presented NASA with a developed proposal in the late 1980s. It was too revolutionary, ahead of its time. At the 1991 International Space Development Conference in San Antonio, in my stead, Mark Kaehny presented a paper on **"Lunar Hostels: An Alternate Concept for First Beachhead and Secondary Outposts",** Peter Kokh, Douglas Armstrong, Mark R. Kaehny, and Joseph Suszynski, © 1991, The Lunar Reclamation Society, in which we described a "big dumb volume" option dubbed "the donut" - an inflatable torus enclosing a "works core."



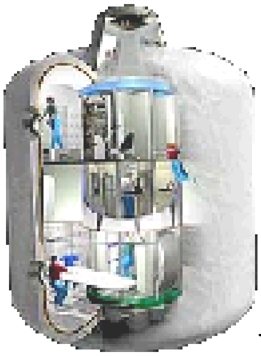
http://www.lunar-reclamation.org/papers/hostels_fig7.gif

The TransHab structure would likewise be centered on a central works core, but its much thicker (12") envelope, designed to protect against the space debris in low Earth orbit, would take up so much space in the transporting shuttle payload bay, that the full inflated size of TransHab would be much more modest than that which we had foreseen as possible: an inflatable promptly covered with a blanket of lunar moondust could have a much thinner envelope that offers a much habitable area room inside.



Thickness of envelope needed makes all the difference

Fast Forward: Bigelow Aerospace, Las Vegas



Bigelow has developed the TransHab technology well beyond the level achieved in Houston through 1999.

TransHab was seen as a vertical cylinder, with as many as three floors perpendicular to its central Axis.

The full size Nautilus module being developed in North Las Vegas is a 22 ft wide (tall) by 45 ft long horizontal cylinder presumably with 2-3 floors parallel to its axis. But all the evidence is that Bigelow is planning horizontal outfittings.

For use in space in a micro-G environment, where there is no effective "up"/"down" the choice between vertical and horizontal outfitting would seem to be a matter of ergonomic plusses and minuses For Moon or Mars bases, a horizontal orientation is much easier to shield, something lost on the Mars Society.

Pre- or Post-Outfitting?

The TransHab and the LRS-designed "donut" or "moonbagel" with their works-packed core choose a design path that pre-endows the inflatable torus with much of its outfitting needs. The core can hold all the utility systems, a galley kitchen, a bathroom. Floor and wall framing can be built into the core to "fold-down, pull out, etc." after inflation. Pre-outfitting, to the extent feasible, removes the need for post-outfitting that may involve many man-hours in cumbersome spacesuits, with attendant dangers.

This is not a moot question. How to post-outfit was one of the biggest challenges for those who a generation ago sought to design ways to reuse shuttle External Tanks, which could have been brought to orbit, even parked in high stable orbits, at minimal extra expense. The most elegant suggestions included:

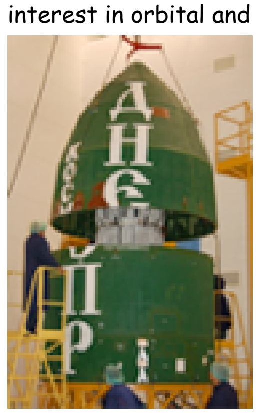
a. Building "purchase points" into the skeleton of the ET: it could be argued that the existing skeleton already was "purchase" or "attachment-friendly.

b. Designing a long thin works core, which could be slid insice the empty (or residual fuel) and parked tank through the 1 meter wide access port at the bottom. The writer does not know if that 1 meter is the size of the opening clearance or of the hatch cover.

At any rate, even if the inflatable envelope now being tested in space under real low Earth orbit debris conditions passes the test of time - it will be watched for leaks for the next several years - there will be more to supplying habitable inflatables than just the protective inflatable envelope. Later modules will test life support and power systems. Still not enough.

Bigelow could help its cause by seeking design input

What Bigelow has designed is akin to an empty airliner. Airlines placing orders pick from a variety of cabin layouts the manufacturer offers, or can ask for custom layouts, no doubt at a custom price. Bigelow may want no help. But it could publish the interior specifications and note any envelope features that suggest ways to sub-divide or structure the interior. And then the company could run design competitions for outfitting layouts and outfitting methodologies. Such a competition would not only guarantee more choices in less time, but greatly enliven the public imagination of the possibilities along with their anticipatory interest in orbital and circum lunar tourism horizons ahead.



The Road Ahead: fly & test: The 8 ft wide by 14 ft long 1/3rd scale Genesis I test module is the first of several Bigelow plans to launch in the near future. This photo shows the pre-inflated module being placed in the Dnepr rocket faring. There is ample room inside the faring to fly the next stage, a 45% scale module, "Guardian," two of which to be launched next year.

"Guardian" will test life support and power generation, not provided on the Genesis module that is testing how well it stays inflated and functions in real space.

The first Destination-minded "Start-up"

While SpaceHab began making pressurized modules for use in space 20 years ago, Bigelow Aerospace is the first contractor to design and build habitable spaces: modules to provide living space. The outlook is bright for its Nautilus modules to help expand the Space Station, to serve in clusters as commercial space stations and tourist hotels, and even "elbow room" habitat space on the Moon!

‹MMM›

[A Segue to last month's "Ceres" Article]

MOON BASE? MARS BASE?

Rock On! Far(ther) Out Man!

by David A. Dunlop dunlop712@yahoo.com

The beginning of the Moon Base agenda story is the rationale and description of the work required to develop a lunar base at its several purposes. The next phase is the rationale and description of the work required to develop a Mars Base and to settle and develop Mars. Kim Stanley Robinson has given us his grand trilogy Red Mars, Green Mars, Blue Mars for that.

Beyond Mars

But, once we have nuclear propulsion to greatly shorten the involved transit times and with it greatly reduce the vulnerability to cosmic rays and solar flares, there are other places that may provide settlement and base opportu-nities farther out.

Beyond Mars is the asteroid belt. With a mature technologies base including all those needed for the bases on the Moon and Mars we can see the potential to advance another step.

John Lewis' book "Mining the Sky" gives us a rationale for going to the asteroids that for the most part are too small and too poor for consideration of a significant manned base. If there is a case for the Moon, and a case for Mars, *is there a case at all for asteroid settlement?*

Certainly, if a case can be made for a base on an asteroid it is likely to be of a lower priority than "humans to Mars." Such an effort will require a mature nuclear propulsion transportation technology to deliver what is needed at such distances. A higher level of self-sufficiency will be needed, higher, even, than that needed for Mars. It' will be a pretty long supply chain if essential in situ resources are not available or cannot be developed.

It seems unlikely in the near term that we can realize significant commercial & financial returns for the effort and expense. Perhaps for purposes of astronomy and other sciences and as a base for obtaining especially strategic asteroid resources, a case can be made.

But for the sake of argument, assuming that these issues are no longer a problem, let's consider the physical scale of the first ten asteroids and a few others.

The great bulk of meteorites fall into either of two categories. The most common (92%) are the S-Class Stony meteorites. These are composed mostly of rock: Metal oxides and various silicates. Next in frequency of occurrence (5.7%) are M-Class Metallic Iron/Nickel meteorites.

Since it is presumed that most meteorites come from asteroids from which they were separated by impacts, many asteroids are of S or M Class designation. These classes differ in composition quite clearly in comparison both to each other and to the Earth's crust. *See table 2 ⇒*.

TABLE 1: Some Candidate Asteroids

#	Name	Diameter (equatorial,	polar)
1	**Ceres**	975 km	909 km

Comments: Spherical, mantle of water ice wrapped around rocky core with thin dusty crust. May have greater volume of water than Earth. Surface area 5 times that of Texas, equal to India. NASA's ***Dawn*** Probe is scheduled to orbit Ceres from February to July, 2015.

#	Name	Diameter (equatorial,	polar)
2	**Pallas**	570 km	525 km x482

Comments: Not spherical. In an orbit inclined by 35° to the general solar plane, requiring more energy to reach

#	Name	Diameter (equatorial,	polar)
3	**Juno**	246 km	
4	**Vesta**	525 km	

Comments: Not quite spherical, 5hr 20.5 minute day, geologically diverse a large impact basin as well as lunar like basaltic maria formed from magma probably melted by radioactive isotope of aluminum. NASA's ***Dawn*** Probe is scheduled to orbit Vesta from October 2011 to April 2012.

#	Name	Diameter (equatorial,	polar)
5	**Astraea**	167 km x 123 km	
6	**Hebe**	205 km x 185km x 170km	
7	**Iris**	209 km	
8	**Flora**	140 km	
9	**Metis**	365 km	
10	**Hygiea**	430 km	
226	**Eugenia**	226 km	
216	**Kleopatra**	217 km	
2060	**Chiron**	180 km	

Comments: Centaur class (orbit beyond Saturn) and Classified as comet

TABLE 1I: Composition Differences between
Column 1: Metal Meteorites & Asteroids (5.7%)
Column 2. Stony Meteorites & Asteroids (92.8%)
Column 3. Earth's Crust

Element	**1**	**2**	**3** Earth Crust
Iron	91.0%	26.0%	5.0%
Nickel	8.5%	1.4%	0.007%
Cobalt	0.6%		(25ppm)
Oxygen	36.0%	49.0%	46.6%
Silicon	18.0%	26.0%	27.7%
Magnesium	14.0%	1.9%	2.1%
Aluminum	1.4%	7.5%	8.1%
Calcium	1.3%	3.4%	3.6%
Sodium		2.6%	2.8%
Potassium		0.4%	2.6%

Outbound from Mars

Mars will be a big bone to chew on. The investment of exploration and colonization of Mars will be dependent on the profitability and infrastructure development that results from commercial development of the Earth/Moon economy. I suspect the resources for a human colony will be a long way down on everybody's priority list (everybody on Earth, the Moon, and Mars) especially because of the low G conditions and lack of a significant economic return on that investment. At some point it may be an "affordable" science luxury to go to Ceres like Antarctica is for us in our time. [continued next page below Table 3.]

TABLE 3: Other Meteorite & Asteroid Classes

There are quite a number of spectral classes and beyond the M Class and the S class they do not all look alike, if you're a spectrometer. Fourteen spectral classes are listed below, with examples given of notable or well-known asteroids. from information listed at: http://www.daviddarling.info/encyclopedia and at http://www.space.com/scienceastronomy/solarsystem/asteroids-ez.html

A Class - Reddish color, olivine: E.g., #246 Asporina
B Class - Carbonaceous Chondrite subcategory #2 Pallas
C Class - Carbon-rich Meteorites / Carbonaceous Chondrites: Examples #10 Hygiea, #253 Mathilde
D Class – reddish: Examples Jupiter Trojan, Hektor; Phobos & Deimos Mars moons (suspected Trojan Origin)
E Class - rare, often Earth crossing, similar to M Class & P Class. Examples Hungaria Family
F Class - C Class subcategory - UV absorption features; Examples: Nysa-Polana Family, #45 Eugenia (226 km)
G Class - Subcategory of C Class strong ultra violet absorption. Example #1 Ceres, 568 miles in diameter
M Class bright, reflective, metallic iron & nickel Spectrally similar to E Class & P class; Examples: # 16 Psyche 248 km, #216 Kleopatra
P Class - dark type, spectrally similar to E class, or M Class but lower albedo: E.g. #87 Sylvia 282 km wide
Q Class - fairly bright, rare. E.g. #1862 Apollo and a few others near Earth asteroids similar to ordinary carbonaceous chondrites
R Class - extremely red, with high albedo: Example: Dumboska, most reddish object in the Solar system
S Class - bright, slightly red olivine & pyroxene stony, Iron. E.g. #3 Juno, #7 Iris 208, #29 Amphitrite
T Class - low albedo, rare: Example #114 Kassandra
V Class - high albedo, pyroxene: Example #4 Vesta

[continued from above] This could well be a century or more from the present and it might also represent a biolo-gical frontier of genetic engineering a subspecies better adapted to low G living. Ceres might therefore represent a strategic adaptive opportunity out of all proportion to its small mini world size. It may be the place where Homo Ceres is developed at the very limits of human society and poised for a break out from the warmth of our native star.

At the first blush it seems that the early best candidate for humans is Ceres that might provide essential in situ resources and become the water station for the asteroid belt. If there is an economic rationale for obtaining metals the water on Ceres might provide the critical in situ resources that enables an Astronomy site and "deep space" settlement that could develop a reasonable level of self sufficiency and provide support logistics for exploration and utilization of asteroid resources. It is hard to think there will be many other near term resources & economic incentives for development for the level of effort and infra-structure needed at this last stop in the inner solar system low G station.

Beyond the inner asteroid belt are the small cold moons of the outer gas planets. These places are far too cold for consideration of human presence unless there were a mature fusion technology and boundless ability to utilize Helium 3 from the atmosphere of Neptune. Without the Helium fusion technology the distances and temperature scale of the outer solar system make proceeding beyond the asteroid belt highly problematic.

Nuclear fission reactors are of course developed technology and provide sophisticated long term propulsion and power technology for the nuclear submarine fleet and the super carriers. Why not just put one of these puppies in a large "2001 style" spinning torus structure and use high ISP ion drive rockets to accelerate to speeds which will allow human to visit and traverse the outer planets, the Kuiper Belt or even the Oort Cloud? Fission reactors put out a large neutron flux that gradually degrades the reactor vessel and leaves the remaining material as radioactive waste. For the distances and long operational life needed to visit and settle on these very cold objects fission reactors seem too much of a stretch.

By preference most people wouldn't give serious consideration to settlement in these cold remote places. For those brave few who can face a frolic in the low G cold, we shall continue this icy-lite conversation where Homo Ceres is poised for breakout! By mixing in some of those carefully preserved Zubrin genes some member of Homo Ceres will write "The Trans Neptunian Cases for Pluto and Zena UB313

Pluto, with a status as the 9th and last of the planets, and as the first of the Kuiper Belt Object" with an inclined orbit of 17 degrees, has a diameter of 1,403 miles, a rotation period of 6 days and 9 hours and orbits the sun in 248 Earth years. It has 0.2% of Earths mass and is 39 AU from the Sun. The International Astronomical Union considers Pluto to be the first member of the class of Trans Neptunian Objects. Pluto's largest Moon is Charon with a mean diameter of 1212 km and two new small additional moons [Nix and Hydra] have been discovered.

By Golly Clyde Tombough! Pluto is a system!
www.space.com/scienceastronomy/solarsystem/pluto-ez.html

More than 800 Kuiper Belt Objects (KBO) have been found since 1992 when QB1 was found. (Solar System Surprise: A New View of What's Out There: Nov 24,2004
www.space.com/scienceastronomy/mystery_monday_041122.html

Xena, 2003 UB 313 has a diameter of 2,100 miles, half again as large as Pluto, and comparable to the Moon's 2160 miles. Its orbit moves from 38 to 97 AU over 560 years inclined 45 degrees to the main plane of the ecliptic. Xena might be seen as a planet: it is larger than Pluto, and also has a moon. Its reflectance is high as it's atmosphere is frozen out. Its temperature ranges during its orbital period range from -405 °F to -360 °F. Caltech's Mike Brown and colleagues Chad Trujillo and David Rabinowitz discovered this. It will take some time to explore and characterize this new real estate. Even with the limited catalog that exists now these big places represent the Manifest Destiny of Homo Ceres.

Sedna, 2003 VB12 is a KBO about 3/4ths the size of Pluto with an upper size limit of 1,000 miles diameter was found two years ago found by Caltech astronomer Mike Brown' Team, and takes 10,000 Earth years to orbit the Sun. **2003 EL61** has a diameter of 1200 km, is smaller than Pluto and has two small satellites. **Quaoar** another KBO was discovered in 2002 has an estimated diameter of 780 miles and orbits the Sun every 288 Earth years. **Orcus, 2004 DW** has an estimated diameter ranging from 840 to 1170 miles with a best estimate of 994 miles and is nearly 47 AU from the Sun. Over 11 KBO with more diameters of 1000 km plus are listed at www.ifa.hawaii.edu/faculty/jewitt/kb.html

Living Nearby, not "on" - Perhaps even larger objects will be found with a higher gravity and a plentiful mix of resources, and with adequate mass for underground protection of high-energy cosmic radiation, that could be considered for eventual human occupation. For extreme environments such as these, the issue is not really settling other "asteroids." Humans will not directly experience such places. Humans will live in "built environments" constructed from the materials derived in such places. Unlike the O'Neill cylinders envi-sioned in the 70s these environment will not be built to take advantage of a large solar flux but to provide a secure heated stable environment against the terrible cold of a 3° Kelvin background environment. But these settlers cannot live indefinitely without new sources of fuel. Therefore, we must become a low G wanderer species looking for Helium 3 in all the right places.

Want to Get Away? The limitations of energy technology aside, why would humans want to settle out there? Ideological reasons that would want to make some people settle away from the cultural challenges they face in the inner solar system. Like the Pilgrims they might choose to define their existence apart from a majority religions population they wish to escape. Perhaps they could not sustain their cultural and religious identity in the face of unrestricted competition from other groups. Perhaps there are groups who would flee the IRS, so to speak and rather build their own world rather than life subject to a larger political context. The decision to "create" Homo Ceres is a critical change in biology and in destiny and functional identity

Redesigning Ourselves - Perhaps the lesson of the inner solar system is that terrestrial Homo sapiens is not well suited biologically to live in a low G environment. With a solar system economy ranging from 1G on down to the mini-G levels of large asteroids in the inner belt it may come to pass that genetically engineered subspecies will be bred to better survive the low G settlements. These new humans would not look to the Earth as their home or to the Moon or Mars as their home because of the intensity of the gravity wells. Someone born on Ceres would weigh 6 times normal on the Moon! Homo Ceres, seeking new opportunities, might be the leading edge of humanity beginning on Ceres and then moving far out in the Kuiper Belt and Oort cloud, away from the warmth and abundant solar power of the inner system.

Transitions: These new humans might "island hop" from such cold objects to others identified even farther out until they find something orbiting in the province of another star and thus transition out of our solar system to another system. After so many generations apart from a planetary existence they will have no emotional tie to our sun. It will be only another star and at one point no longer the closest star.

Such island hopping might continue from the outer regions of one star to another even if there were no identified Earth like planets around a number of stars. *Even if we find other Earth like planets, the human-derived species that make the journey may not be able to settle on a larger high G environment unless they reverse engineer their genetics.* They would then once again be trapped on a single terrestrial ball in a "wild and extreme" environment with no guarantee of easy settlement. Looking at themselves and the rich and terrible tradition of human development and history on Earth is not necessarily motivating. *Would they as an interstellar adapted species want to "Play It Again Sam" on a new earth even with the attractions of a stable sun for another billion years?* Why would they want to go back if the outer regions can commonly provide resources for continued travel? If new planets had their own life, the biological problems of adaptation and coexistence reappear.

Impossible.? The cliché "Where you stand depends on where you sit" would seem to apply to this evolutionary set of choices. If we can supply ourselves a body well adapted to an Earth-like planet that is mostly a marine world would we reengineer our selves to be an intelligent marine mammal or an intelligent terrestrial species? Which environment is more attractive, comfortable, and better able to provide a stable base for an intelligent species? Perhaps several intelligent species would be bred under such circumstances.

Perhaps on the other hand the picture presented in the film "Independence Day" of a migratory interstellar species is instructive. *That* species with advanced technology and mega "built environments" moves from planet to planet stripping them of resources needed for its own purposes, then moves on. This could be the evolutionary tactic used to sustain mobile existence for a large number of individuals maintaining a high technology culture in the galaxy.

The development of Moon and Mars base technologies may lead not only to a variety of distant places but to distant and different identities. *Far Out! Man!* **<MMM>**

The Challenges of Migration into the Cold & Darkness of the Outer Solar System

By Peter Kokh

We are not yet back on the Moon, have not yet made our first footfall on Mars. But that does not stop our Ad Astral aspirations from trying to project our presence further out: on the asteroids Ceres & Vesta, on Jupiter's Callisto and Europa, on Saturn's Titan & Iapetus, and ever beyond. It is part of the process of imagining far away places from a frontier-perspective.

It will be quite some time before there is any con-certed effort to "talk up" and "think out" human expeditions beyond Mars. But that day will come. When it does, what we imagine as possibilities today, may seem quaint, Jules Verne-ish to those who follow with access to science and techno-logy that we can only dimly glimpse. Going further out, will, however, be challenging to the extreme.

These challenges are threefold. As we go further from the Sun, the amount of light and warmth we receive from it diminishes with the square of the distance: at twice the distance there is only one fourth the light and heat. This makes solar energy collection ever more difficult and less feasible a way to derive power. Surrounding space gets ***ever darke***r, ***colder and colder.***

The spacing between planets gets larger and larger. Low energy Hohmann transfer orbits take years, decades, even centuries, not just months as on the way to Mars and back. Places to visit become ***ever further apart*** from one another. Trade in supplies and goods will become increasingly more difficult, let alone journeys by individuals whether for business or pleasure.

Because of the greater heat in the inner solar system at the time of planet formation, the inner system planets are predominantly rocky: silicates and metal oxides. Further out, the proportion of ice and water, and other volatiles in comparison with rocky elements becomes greater and greater. Indeed, on the icy moons of Jupiter, Saturn, Uranus, and Neptune, and probably the more so on KBOs and TNOs - Kuiper Belt and Trans-Neptunian objects, while water, oxygen, nitrogen, and carbon are abundant for life support, the challenge will be to extract metals for tech-nology. The situation we find on the Moon is stood on its head further out. That could discourage development of human frontier exclaves except in locations where a happy medium can be found.

Perhaps nowhere will trade be more necessary, and at the same time, more difficult to the point of futility, as anywhere in the Outer Solar System except within the planet-moon systems of Jupiter, Saturn, Uranus, and Neptune, a complementary full suite of needed materials may be a very rare occurrence..

What we stand to learn on Ceres

On Ceres, the next likely frontier beyond Mars, the availability of both volatiles and rocky elements in an appre-ciably colder (than Mars) environment, makes a frontier settlement there the ideal testing ground for a greater reliance on new cryoplastics, synthetics build of volatile elements but tolerant of temperatures significantly lower even than those we find in the lunar night or in the Martian winter. If it proves possible to develop a versatile suite of such cryoplastics and cryo-synthetics, then we will be prepared for the Moons of Jupiter and beyond, as far as the material side of human existence is concerned.

While solar power becomes ever more impractical a solution, the further out we go, we might still find a use for it on Ceres. A collector 1 meter on a side on Earth or the Moon would have to be scaled up to 3.5 meters on a side, seemingly quite doable. Nuclear power in some form seems sure to become the solution of choice.

The danger from solar flares will lessen as we go further out, but not that of cosmic radiation. Ice will become the shielding material of choice.

Transportation will be the biggest challenge. Goods and cargo can always be shipped in a continuous pipeline fashion, unmanned ship after ship. How long it takes to go through the pipeline is irrelevant, so long as the "faucet" is always spitting something out on time, and in the amount needed. Special orders, however, will take years, even decades or centuries to fill. That will put an ever greater urgency on achieving the highest degree of self-reliance. And that means settling only where *all* the needed elements are economically available. As we go further out, an ever-increasing number of worldlets will not pass that muster.

The low gravity question

Callisto, Ganymede, Europa, Io around Jupiter, and Titan around Saturn have gravity levels between 19% and 15% normal, comparable to the Moon's 16+%. A population adapted to lunar gravity will have no difficulty adjusting to life on those large satellites. We can hope that the physical deterioration we see in Earth orbit will level off at an acceptable level in lunar sixthweight, meaning that not only will our offspring be healthy, but theirs in turn.

However, physiological zero-gravity occurs when the friction within blood vessels is no longer overcome by the gravity gradient. The only instrument worth reading is the body. Ceres' 3% gravity may flunk the test. If so, we will become increasingly reliant on artificial gravity. Bioreengineering ourselves is unlikely to be an early generation choice. That is not a new idea. Read "The Seedling Stars (Paperback) by James Blish, Publisher: Roc (1959), ISBN: 045101622X, available from Amazon.com."

One danger that may become a growing problem, is that frontier settler groups may depart with too shallow a gene pool, forcing on them a degree of inbreeding that could spell doom. The outward drive will be an epic saga!

<MMM>

Teleoperation: How far can we push it?

Contestants racing teleoperated rovers over a set course, with practice, could conceivably anticipate turns and other routine maneuvers so as to reduce notably the 2.4-2.8 second lag between command and evidence of execution. But as we try to teleoperate ever more complex equipment to perform ever more complex routines, teleoperators on Earth will have to become more cautious, yet will routinely work 125-400 times faster than those who teleoperate Mars Rovers. More on the challenge, *below.*

Technologies Needed to Break Free

by Peter Kokh

Despite the best of current announced intentions, it is politically and economically predictable that NASA's lunar outpost (even if is "internationalized" by taking on "partners" in a contract) will be stripped of any and all features seen as "frills" or "extras." Consider how the planned 7-man International Space Station was summarily slashed without partner consultation in the stroke of a presidential pen to a 3-person one: 2.5 persons needed for regular maintenance and a half-person is available for scientific research. It can and will happen again, *unless ...*

It becomes our cause, the accepted challenge of those of us who owe it to our own dreams, to do everything in our power to get the outpost built, outfitted, and supplied on a more rigorous and stasis-resistant path. The/a lunar outpost must be designed with expansion in mind, with a suite of easy expansion points, expressing an architectural language that is expansion-friendly. No all-in-one "tuna can stack", please!

To this end, we must reexamine *every aspect and angle* of setting up a lunar outpost.

I. Transportation System Architectures:

Designing cannibalizable items for strategic reuse in Earth-Moon Transportation Systems.

NOTE 1: The author is *not* a rocket scientist, engineer or architect. The examples given below may not all be feas-ible, but we hope that those that are not, will suggest other possibilities that are worth exploring.

NOTE 2: We do *not* expect NASA to embrace any revolutionary space transportation system architectural turnabout. But it is something that commercial space transportation providers might do well to study.

NOTE 3: Those in the business may be quick to insist that these ideas are all impractical. So be it. They are not part of the solution. We are looking not for those who say "it can't be done," but for those who say "we'll find a way to do it anyway!" If it were not for the "Young Turks" in various fields, we would all still be swinging from the trees. We must find the hidden, unsuspected pathways!

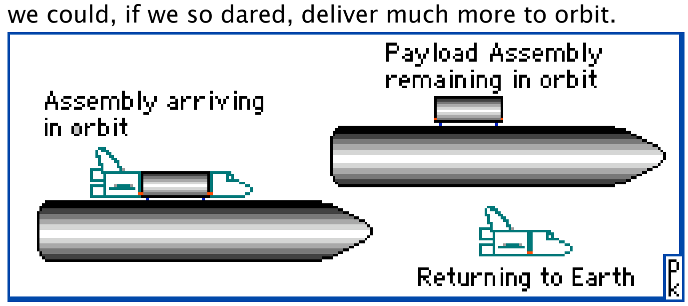
Way back in MMM #4, April 1987, we pointed out that Marshall McLuhan's dictum that "the media is the message," might be transposed to "the rocket is the payload." Of course, you can only push this so far. But this daring architectural philosophy offers the best way to escape the imagined, unnecessarily self-imposed tyranny of the mass fraction rule. "Of the total weight, 91 % should be propellants; 3 % should be tanks, engines, fins, etc.; and 6 %t can be the payload."

http://www.allstar.fiu.edu/AERO/rocket5.htm

We are not talking about exotic fuels or better rocket engines, but ways to include the 3% "tanks, engines, fins, etc." into the payload.

In the case of the Shuttle, the mass of the vehicle is much greater than the mass of the payload, so we do not come close to the ideal. At the time (the April 1987 article), I offered this simple example. In the shuttle space transportation system, the payload that gets to stay in orbit is a needlessly small portion of launch vehicle mass.

Adopting philosophy "the rocket is the payload" we could, if we so dared, deliver much more to orbit.



In the suggested alternative, the orbiter has a fore and aft section: Crew Cabin and Engine pod with much smaller wing/tail assembly. There is no payload bay. A much larger payload, with a lightweight faring if needed, takes its place. The External Tank is also placed in orbit as part of the payload. A stubby shuttle is all that returns to Earth. Savings include not just the payload bay section but the much lighter smaller wings and tail. The article referred above to is reprinted in MMM Classic #1, p 10, a freely accessible pdf file at:

www.moonsociety.org/publications/mmm_classics/

Again, don't waste time writing MMM with all the reasons this couldn't be done. Instead, consider yourself challenged to figure out how we could do this anyway.

This is only one suggestion of how we can "cheat" the mass-fraction "rule." The shuttle system will not figure in the establishment of a lunar outpost. So it is not these details, but the spirit behind them that we are trying to get across. *Attitude, attitude, attitude!*

Terracing the way back to the Moon

It seems unlikely that the Lunar frontier will be opened with vehicles that depart Earth's surface, make the entire trip out to the Moon, and land on the Moon's surface directly. So what we have to examine is all the various parts:

- Earth surface to LEO (low Earth orbit) transports
- LEO to Earth Moon L1 or Low Lunar Orbit ferries
- Lunar orbit to lunar surface landers

At each phase, if the vehicle addresses the design challenges, material and/or useful assemblies and sub-assemblies can be deposited at the next. Whether it be all in one ride, or by a succession of waves, more payload gets delivered to the Moon's surface, and/or more robust way stations are constructed in LEO and LLO (low Lunar orbit) or at the L1 Lagrange point. *No opportunity is missed. See* "The Earth-Moon L1 Gateway" MMM #159, OCT 2002. You can download this issue freely at:

http://www.lunar-reclamation.org/mmm_samples/

We would be remiss if we did not point out that one of the most brilliant components of the **Artemis Project**™ Reference Mission architecture involved just such a mass-fraction cheating device: reduction ot the portion of the landing craft that "returns" to the open-vacuum "space motorcycle" I think it can be shown that most objections to this design as vulnerable to micro-meteorite impact are baseless. Micrometeorites strike the Moon, and spacesuited astronauts!, on the surface, with velocities much higher than the velocity such a craft would need to reach lunar rendezvous orbit. It was the incorporation of this feature that allowed the Artemis Project™ ferry to deliver the relatively massive triple unit SpaceHab-based outpost core to the surface.

Whether the Artemis Project™ Reference Mission will fly as designed is not our topic and irrelevant. The point is that it demonstrates, at least in this instance, the kind of breakthrough paradigm-scuttling innovation that alone will get us to the Moon "to stay."

Stowaway Imports: smuggling more to the Moon

Another article we wrote that suggests ways to "smuggle" more useful material and items to the Moon is "Stowaway Imports" in MMM #65, May 1993. This article is republished in MMM Classics #7, freely downloaded at www.lunar-reclamation.org/mmm_classics/ - or at www.moonsociety.org/publications/mmm_classics/

The idea here, is that it is inevitable that there will be structural, outfitting, or packaging items aboard craft landing on the Moon that are not needed for the return to the vehicle's base, be it in LLO, LEO, or Earth itself. The cost of getting these items to the Moon is prepaid as part of the cost of getting the payload consist to the Moon, whether or not they remain on the Moon or not. So if we leave them there, these items are a bonus.

Packaging containers, stuffing, dividers, etc. can be made of items not yet possible to duplicate on the Moon: some Moon-exotic element such as copper, or an alloy, some reformable plastic, biodegradable materials useful as fertilizers, nutritional supplements, *whatever.* Everything not absolutely needed for the ride back is game for scavenging. On crewed vehicles this can consist of everything from tableware to bedding, to appliances and even cabin partitions.

Some items can be thoughtfully predesigned for second use on the Moon as is. Others will be melted down or reformed for the useful material they contain. It's all free, or at least at less cost than replacing them for the next outbound trip to the Moon. Only the "squeal" need return!

Designing moon-bound craft to be cannibalized in this fashion will require resourcefulness, and exploration of a lot of options, some more promising and less difficult than others. Stowaway imports are a way to supplement what personnel on the Moon will be able to produce or fabricate for themselves, thus leading to swifter development of a more diversified lunar startup economy.

Cargo craft landing on the Moon might be designed for one way use only. Fuel tanks will be prize imports, landing engines may be reusable for surface hoppers. The idea is to build these craft cheaply and in numbers, much in the mold of WW II "Liberty Ships." If some crash or go astray, the loss will not be critical.

In our Lunar Hostel's paper (ISDC 1991 San Antonio, TX - www.lunar-reclamation.org/papers/) we introduced the "frog" and the "toad" - Moon ferry underslung crew cabins that could be winched down to the surface, lower its wheeled chassis, and taxi to the outpost: amphibious space/surface craft. The "frog" would return. The "toad" would be designed to spend the rest of its service life on the Moon as a surface transport "coach."

Modular Transportation

One of the more outstandingly successful innovations of modern transportation is the pod. Cargo in uniformly sized and shaped pods is transported on trucks, flatbed railway cars, and ocean going cargo ships.

The space transportation industry, especially the commercial sector, would do well to develop standardized pods, not waiting upon NASA clues which may never come, simply because the need does not arise in the very limited NASA lunar outpost mission plan. There may be more than one pod design, however, depending on the nature of the cargo. Liquids and aggregate materials (a load of wheat, for the sake of an example) may require container constraints, for shipment through the vacuum of space, that large assemblies do not.

The pod agreed upon would have significant repercussion for modular systems shipped to the Moon: modular power plants, modular water recycling systems; modular regolith processing systems; modular food processing systems; modular hospital cores; the list of possibilities is endless. No one size is ideal for all applications. However, we suggest that the current modular factory system serve as a model and size guideline, as it has proved remarkable successful. See MMM #174 April, 2004 "Modular Container Factories for the Moon." You can download this issue freely at:

http://www.lunar-reclamation.org/mmm_samples/

Such a pod could also deliver inflatable modules to the Moon, which could then be outfitted on location, with cannibalized components and/or items manufactured by startup lunar industries. The result would be quicker build-out of the original outpost structure.

Transportation Systems Architecture Upshot

If we intend to expand the outpost into a real industrial settlement on an "inflationary fast-track" - the only way it can be done economically - the Earth-Moon transportation system must be so-designed from the gitgo, *down to the last seemingly insignificant detail.* A missed opportunity could spell the difference between success and failure. Our purpose in giving the examples above is less to fix attention to our examples than to get across the spirit. Spacecraft architecture, systems architecture, industrial design for reusability as is or with minimum processing effort, choice of materials, etc. And all vehicles at every stage should be designed this way.

Again, these lessons will be lost on NASA as its objectives are strictly limited: to deploy a moonbase in order to prepare for manned exploration of Mars. "." But commercial providers are likely to look for more extensive use of their products, for other more open-ended markets. It is with them that all hope lies. Those that adopt the above philosophy as a cornerstone of their business plans are more likely to survive and thrive long after NASA's government-limited goals are met.

II. An Expansion-friendly Modular Outpost Architectural Language, and Construction/Assembly Systems Design

Back Reading:

MMM #5 May '87 "Lunar Architecture", MMMC #1
MMM #75 May '94 "Lunar-Appropriate Modular Architecture" MMMC #8
MMM #101, Dec. 96 "Expanding the Outpost", MMMC #11

This is one area in which the **Russian**s and **NASA** with its various **contractors**, have already done considerable research and have acquired invaluable inflight/inuse experience in the **Mir** and **International Space Station** programs. Happily too, a commercial contractor, **Bigelow Aerospace** is now making groundbreaking contributions with inflatable module technology, borrowing heavily on NASA's Congress-aborted TransHab project. The prototype one quarter scale inflatable **Genesis I** is now in orbit and rewardingly performing well.

Modular architecture developed for the microgravity of Earth orbit will certainly have applications in the return to the Moon effort. It will apply directly to any way station developed at the L! Gateway point or in lunar orbit. But applications to the design of lunar surface outposts will need some rethinking for four reasons:

We are now talking about a 2-dimensional environ-ment stratified by gravity, not the any-which-way dimensions of orbital space. The 1/6 Earth normal gravity environment mandates an established up-down orientation, no "swimming" through the air to get from one point to the other. This is minor.

Egress and ingress portals need to be designed to minimize intrusion of insidious moondust. It would be ideal if spacesuits were rethought with this challenge in mind, but NASA has already signaled its intention not to explore that route for money reasons. One more sorry instance of a "stitch in time, saves nine." NASA operations on the Moon will be far more expen-sive to maintain than the relatively trivial expense of wholesale spacesuit redesign even at multimillion dollar expense. Commercial contractors may be the Knights in Shining Armor here as the NASA approach would be indefensible in any business plan.

Outside the safety of the Van Allen belts, radiation protection is required for more than short stays. The lunar surface station must be designed to sit under a shielded canopy, or to be directly covered with a regolith blanket. An added benefit will be thermal equilibrium.

While NASA, its contractors, and the Russians have a head start, it should never be assumed that they have explored all the options. Modular architecture is very much structured like a language: it has nouns (the various habitat and activity modules), conjunctions and prepositions (the various connector nodes), and verbs (the power system, the Candarm and other associated assembly and arrangement tools). The idea in constructing a "lunar-appropriate modular architectural language" is to come up with the most versatile, yet economic in number, set of modular components to support the most diverse and varied layouts and plans. The idea here is to maximize the options for expansion, without prejudging what needs will be accommodated first in the buildout.

We think that this concept is important enough to put to a design competition. NASA, contractors, the Russians can all advise on interface constraints and other design features that must be incorporated. Then let the would be Frank Lloyd Wrights of the lunar frontier have at it. We predict some novel suggestions that NASA and commercial contractors may want to adopt.

We have suggested in Part I of this article, that modules should fit (yet-to-be-)standardized Earth-Moon shipping pods. The cheapest way of providing maximum elbow room, in the era before modules can be manufactured on the Moon out of lunar building materials, will be inflatable modules. Easy to deploy "outfitting systems" for these inflatable units are another area worth exploring through the device of an international design competi-tion. The inflatable manufacturer can set the constraints which will include interior dimensions, purchase points, and ingress opening sizes. Then let the contestants exercise their varied inspirations.

Onsite manufacturability of needed components would be a design goal: maximum use of low-performance cast basalt, glass composite, and crude alloy items should be the preferred contest category. This way, expansion develops hand in hand with early startup industries, and becomes a strong incentive for their earliest development, saving substantial sums over importation from Earth.

Expanding on this theme, even equipment in hard-hull modules arriving fully outfitted from Earth might be limited to subassemblies of components not yet manufacturable on the Moon. A very simple example would be cabinets, tables, floor tiles, even chairs without horizontal tops or seats. These could be made of cast basalt, saving some weight in shipment. Many more possibilities of this compound sourcing paradigm are worth exploring: wall surfacing systems, simple utensils, appliance chasses, etc. See MMM #18, Sep. '88, "Processing with Industrial "M.U.S./c.l.e." reprinted in MMM C #2.

We mentioned the need for shielding. The development of simple canopy framework systems that can be locally manufactured, then covered with regolith, would be invaluable. Such canopies could protect stored fuel and other warehoused items that need to be accessed regularly, so that personnel could do these routine chores in less cumbersome pressure suits as opposed to hardened spacesuits. Such canopies could also serve as flare shelters out in the field at construction sites or at periodic points along a highway. An easily assembled (teleoperated?) space frame system with a covering that would hold a couple of meters (~yards) of regolith should be another design contest goal.

Modular Power Generation, Storage, and Heat Rejection Systems

This is a suggestion that NASA may well not bother considering. The initial outpost power generation and storage systems and heat rejection systems should be designed with modular expansion in mind. NASA will not be reflecting on the needs of expansion because its government mandate does not extend to expansion, unless space advocates force a change, even if "just to leave the door open for commercial developers who may follow." We think such activism is worth the effort.

Introducing Load-based Modular Biospherics

In our opinion, NASA's performance in developing life support systems has been hit and miss. Chances to incorporate a higher level of recycling on the Space Station were passed up in the name of up front economies, even though such systems will be absolutely vital on the Moon and Mars. To its credit, the agency does have the BioPlex project in full swing in Houston. But we worry that the outcome will be a centralized system that will work for the designed size of the lunar outpost, and not support further expansion.

The centralized approach to biospherics has a famous precedent: Biosphere II. We think centralized approaches are not the way to go. Instead, we should develop load-based decentralized systems. In this approach, wherever there is a toilet - in a residence, a workspace, a school, a shopping area, a recreation space, etc. there should be a system to pretreat the effluent so that the residual load on a modular centralized treatment facility is minimized. The Wolverton system is what we have in mind.

If all outpost modules with toilets have built-in pretreatment systems, then, as the physical modular complex grows by additions, the "modular biosphere" will expand with it. Expansion will not race ahead of the capacity of the contained biosphere to refresh itself.

Another essential element of modular biospherics is having plants everywhere. A phone-booth sized salad station will not do. Useful plants can be grown through-out the lunar outpost: they can provide additional salad ingredients and meal enhancers: peppers, herbs, spices, even mushrooms. Even decorative foliage and flowering plants help keep the air fresh as well as provide a friendly just-like-home atmosphere. Plants in front of any window or viewing portal would filter the stark and sterile barrenness outside.

Plants must not be an afterthought. We cannot long survive, let alone thrive as a species that hosts houseplants. We *are* a species *hosted by* the lush vegetation of our homeworld. We should never forget this. We cannot go with the attitude of "let's build some cities, and a token farm here and there." Rather we must go to build a new vegetation-based but modular biosphere which will then host our settlements.

City dwellers all too easily discount the farm. We have houseplants as botanical pets. That paradigm won't work. Designing all habitation and activity modules to house plants as an integral feature will help allow the biosphere to grow in a modular way along with the physi-cal plant. It will be a more enjoyable place to live as well.

NASA is unlikely to pay these suggestions a glancing thought. We hope that commercial contractors, whose long range plans are not limited by governmental myopia are more farsighted. Modular biospherics should be part of their business plans for any industrial settlements or tourist complexes on the Moon.

Teleoperation of construction & assembly tasks

So far we have been talking about architectural considerations that would prime any startup lunar outpost for expansion, no matter how restricted its mandated goals. But expansion, as well as original deployment, requires construction and assembly. To the extend that individuals in spacesuits are involved in this work, it will be dangerous and risky. Human manpower hours on the Moon will be expensive to support. Loss or incapacitation of just one person in an outpost construction accident would be a major and expensive one.

In order to maximize crew usefulness and productivity as well as health and safety as many tasks as possible should be designed for remote operation by persons safely inside the outpost or construction shack, or by teleoperation by less expensively supported people back on Earth. The latter option may be more technologically demanding but it is far more preferable. Every construction operation tele-controlled from Earth frees personnel on the Moon for things that only personnel on site can accomplish. The result is progress is surer, safer, and yet quicker. The outpost is up and running in less time, with everyone healthy and ready for real duties.

In the following article, page 7 below, we take up this fascinating topic of pushing the limits of teleoperation, surely a prime area for engineering competitions.

III. Locate for local, regional, and global expansion options

The writer's position on moonbase siting is well known. We have no problem with being all alone in seeing a lunar south polar outpost as a dead end. But we hope that commercial contractors will be more farsighted. The problem is that we need to plan not just one outpost, but an outpost that can be a center from which an industrious human presence will spread across the lunar globe.

In their very well brainstormed proposal outlined in "**The Moon: Resources, Future Development and Colonization**", David Schrunck, Burton Sharpe, Bonnie Cooper, and Madhu Thangavelu present a comprehensive plan for establishing such an outpost at the south pole and for spreading out from that center across the globe via an electrified lunar railroad. We certainly support the latter idea and have written independently on the feasibility of electric lunar railroads.

But we fear that south pole advocates have discounted the dangers of operating in a polar environment, in mountainous terrain, where the sun is always at or just below the horizon *or* immediately above it casting constantly shifting "blackhole-black" long shadows. We also suspect that the difficulty of deploying a solar power tower system in mountainous terrain is not addressed. That the nearest highland/mare "coast" where resources of both terrain types needed for industrialization are accessible is 1,300 miles dopant is another overlooked disadvantage. That sunlight is available 86% of the time does not erase these drawbacks.

Water-ice may exist at the poles. But hydrogen is everywhere on the Moon in the regolith, ready to harvest. As much as we need water, we will use far greater tonnages of other materials. Do we bring Mohammed to the Mountain or the Mountain to Mohammed?

There is, it seems, an unstoppable bandwagon for the South Pole. Commercial contractors interested in developing lunar resources and/or tourist facilities, are likely to take a second look. Our hope lies with them.

A NASA-International lunar polar outpost may survive, minimally manned to tend astronomical observatories in the area. If we mine polar ice preserves it makes more sense to do that in the north polar areas. If the observatories go unsupported, one day, lunar tourists may visit the historic ruins at the South Pole.

Parts IV & following, Next Month

In next month's installment of "**The Outpost Trap: Technologies Needed to Break Free"** we will talk about ISRU, In Situ (onsite) Resource Utilization, processing the most common elements in the regolith and producing building materials. We cannot thrive on oxygen alone! Any effort to do so will end in outpost termination.

We will also explore the ways to get lunar industrialization off on the optimum path to a logical diversification that will build upon itself and reach import-export expense-income breakeven as quickly as possible.

Lastly, we will explore the demands of the most critical of all moonbase systems, without which all the rest, no matter how well designed, will collapse, or at the very least totally preclude civilian expansion of the kind most of us want to see: "the human system". This is the system currently being viewed with the most rusty-hinge horse blinders, and not just by NASA.

Meanwhile, a parting thought

While no one has ever established an outworld outpost before, we humans have certainly had plenty of experience in establishing new frontiers. There is a substantial reservoir of experience here throughout human history and in many human cultures, on which to draw.

Establishing an outpost, whether or not new and complex equipment is needed, is much more than a matter of nuts and bolts, of engineering and rocket science. To rely solely on the insights of experts in those professions will only gain us an expensive collection of hardware on the Moon. It will not gain us the open-ended establishment of a civilian, resource-using presence bent on making itself as much "at home" on the Moon as we have always done, over and over, everywhere that we have pioneered new frontiers on our home world.

In a sense, this will be a second Cradle Breakout. We are, you see, already an *intra*-planetfaring species. We have already settled new "worlds" in our "Continental System" beyond home continent Africa. The next step is only a continuation. But we must rely most of all on our instinctive cultural wisdom based on millennia of experience by endless waves of pioneers who have gone before. The upshot is that NASA and other agencies must fit in *our plan, rather than we in theirs.*

Much of the expertise needed will have to be developed or at least rethought. Here we need to rely not solely on those "tasked" with working on the project. After all, it is our project, not theirs, and no government has the right to exclusively appoint any set of specialists to the task. This frontier like all others, will be pioneered by rebels, by those unhappy with the status quo, by Young Turks who dare to look at old problems in a fresh light, by people who are willing to dust off the countless pages of abandoned research, looking for promising turns in the many "paths not taken."

And we need the entrepreneurs who will develop these new technologies *now, for profitable terrestrial applications,* but ultimately to put them "on the shelf" *just in time* where lunar pioneers can find them when needed.

As a Society tasking ourselves with doing what we can to make it happen, we need to seek out "adventurous expertise", well researched but yet open minded persons who will make the breakthroughs, large and small, that will help realize the drea **<MMM>**

Teleoperation: getting the most productivity from our personnel on the Moon

By Peter Kokh

Tel•e•o•per•a•tion: the remote control operation of untended equipment; radio-control

Actually, "teleoperation" is a relatively new word coined by space development writers. Even though we have been using it for two decades or more, it has escaped notice by those who are supposed to keep dictionaries abreast of the times.

The basic idea is do what we can, remotely, on the Moon, when human on site labor would be expensive, or dangerous, or best reserved for things which cannot yet be easily remotely performed. What makes teleoperation practical on the Moon, but discouragingly tedious on Mars, is the speed of light that governs remote control by radio. At that speed, there is a bit less than a 3 second delay between a teleoperators "joy stick" movement and the observation of the command being performed. Numerous experiments, many of them by enthusiasts, have shown that this small time delay is manageable. On the other hand, anyone attempting to teleoperate a rover or some other kind of equipment on Mars would have to endure a minimum delay 125 times longer, 6 minutes, and a maximum of around 40 minutes. Ho hum! Zzzzz!

Equipment on Mars, a whole fleet of it, in fact, could indeed be easily teleoperated from Phobos or Deimos, but the Mars Society resists the idea of setting up forward outposts on either Mars moonlet, as a "detour." That's their problem. Impatience always bites one in the but, one reason the opening of Mars must be more broadly based. But we digress.

Proposals on the table for teleoperations on the Moon

Over fifteen years ago, it was suggested that mini-rovers on the Moon could be "raced" against one another over a prescribed course, the race watched on television, with the contestants paying for the privilege. The idea was to raise money.

More to the point, it has been suggested that equipment placed on the Moon could be tele-controlled to *grade and prepare a site* for a lunar outpost and once that was in place, the same or additional teleoperated equipment could *cover it with regolith shielding*, in advance of the arrival of the first moonbase crew. These would be time-consuming tasks for human crews. By tele-performing these operations, the crew would arrive at a Moonbase all set to go.

Beyond Site and Outpost Preparation

There will be "too much to do" for the small initial crew right from the outset. Nor will this change when the outpost begins to grow, not even when the first true settlers arrive. It is a truism of all frontiers, that there is always too much to do, that *needs being done,* than people to do it all. Sending people who are each multi-talented will certainly help. But that will not change the fact that there are only so many hours a day, and that there are limits beyond which driving individuals to put out ever more and more will backfire.

More to the point, there is a question of priorities. Somethings are too sensitive and/or too complex to be performed remotely. Hair-trigger responses are needed. On the other hand, there are tasks that are reasonably dangerous to perform, with a high risk of injury, or even death. These considerations give us a basis on which to decide when it is better to teleoperate, and when it is best to have an on site individual perform a task.

Add to that the financial considerations. Each man-hour of work, regardless of the pay scale, performed on the Moon, costs much more than that person's pay. You have to factor in what it cost to send that person to the Moon, maintain him/her there in good health, and to eventually (at least in the early phases of our open-ended presence on the Moon) return the person back to Earth.

It makes even more sense then, to find a way to teleoperate all risky and dangerous jobs, all routine and tedious jobs, and anything else we can do to relieve base personnel of any work we can so that they can get on with doing what only they can do. That way, the outpost, whether it is manned by four or forty or four hundred, can advance more quickly, will get more accomplished, thanks to its ghost army of teleoperators back on Earth.

Yes, we'd all like to see the lunar population to swell quickly to the hundreds, the thousands, maybe someday the hundreds of thousands. Doesn't taking jobs away from real people on location counter that goal? To the contrary, it advances it, because at each stage this pocket of mankind will be more productive, allowing it to grow faster, not just in industrial diversification and export output, but also in numbers. And the extra productivity earned by teleoperations, will make the settlement bottom line more attractive, less a target for budget cutters on Earth. When they arrive, their habitat space will be ready, thanks largely to teleoperated tasks.

What all can we teleoperate?

- Site preparation, grading, road building, excavation, shielding emplacement, repeatable construction and assembly tasks, deploying radio and microwave repeaters, deployment of solar power stations, initial prospecting surveys. (much more, especially in a given time, than Spirit or Opportunity can do), setting charges in road building, gas scavenging, preliminary routine prospecting surveys, lavatube exploration, etc. – *i.e., many tasks that need to be done out on the surface, minimizing EVA hours by personnel in space suits.*
- Tending agriculture installations, routine watering, weeding harvesting, fertilizing, etc.
- Many factory operations, especially dangerous ones
- Desk work, paper pushing, document processing tasks

The priority should be (a) to take care of as many out vac tasks as possible which would be exhausting and cumbersome for people working in space suits, and not without real risk. (ab) exploration of subsurface voids – lavatubes. (b) inside operations which carry some danger. (c) routine, repetitive, and boring tasks to the extent that they cannot be automated. (d) utility and air/water treatment routine tasks, (e) routine inspection jobs, (f) some bureaucratic paper work, minimizing the amount of desk work that has to be done on location. (g) when the time comes, the bulk of routine teaching assignments. Again, one must keep in mind, that teleoperations are to prepare for humans to settle in and live comfortable fulfilling lives.

What we can do now

If we succeed in putting together an aggressive Lunar Analog Research Station program, one thing we don't have to do is prove the value of human-robot teams in field exploration. We have already made that point in the Apollo program years. So practicing lunar geology is not a high priority, nor is field exobiology. The M.A.R.S. analog stations have done great work in this area. Again, we've already made that point almost forty years ago.

On the other hand, the Mars people have no need to demonstrate teleoperations skills, as Mars much greater distance, from 125 to 400 times further from

Earth than the Moon, makes teleoperation impractical – unless they want to come to their senses and realize how much faster the Martian globe could be explored with fleets of minirover probes teleoperated from just above, from shielded stations on Phobos and/or Deimos.

Teleoperation with a 3 second time delay has been demonstrated many times, but mainly in the “driving” of rovers. More complex tasks such as site preparation and shielding emplacement via teleoperation have not been demonstrated. These are challenges suitable for college level engineering teams, and the demonstrations could be done at an analog station. What we’d need for terrain, at least in the area where we would be teleoperating is a *physical analog* of lunar moondust or regolith. The elemental and chemical composition would be irrelevant. The mix of particle sizes and the behavior of the mix in handling would be essential. It would be in NASA’s interest to fund creation of such a site, whether a sandy gravel mix native to the area was further transformed to meet the experiment constraints, or whether the faux regolith was prepared elsewhere and trucked in.

Once site preparation and shielding emplacement techniques were demonstrated, we could ramp up the challenges to include road construction and many other chores we’d prefer not to have done by humans in cumbersome spacesuits, exposed to cosmic radiation. (ab) teleoperated exploration of a nearby lavatube would be possible in some of the sites under consideration (Bend, OR; El Mapais National Monument south of Grants, NM, Craters of the Moon National Park in Idaho). But we could run such tests at one or more of those locations whether we had deployed an analog research station nearby or not. We could also try to develop teleoperable greenhouse systems, water recycling systems, ACC; even though we don’t need to demonstrate human geology field work, we could demonstrate teleoperation of prospecting probes.

The possibilities are many, and will grow with the complexity of our outpost, and its continued growth.

Teleoperators on Earth

These people, whether unpaid volunteers, or paid assistants, should earn status as “lunar pioneers.” For even if they never personally set foot on the Moon, the fruit of their work will be in evidence throughout the area where human settlements spread. **<MMM>**

Hard Surface “Worlds” in the Solar System

1	Mercury
2	Venus
3-4	Earth, Luna
5	Mars
6-8	Ceres, Pallas, Vesta
9-12	Io, Europa, Ganymede, Callisto
13-19	Mimas, Enceladys, Tethys, Dione, Rhea, Titan, Iapetus
20-24	Miranda, Ariel, Umbriel, Titania, Oberon
25	Triton
26-27	Pluto, Charon
28 ff.	Xena and other “Plutonians”

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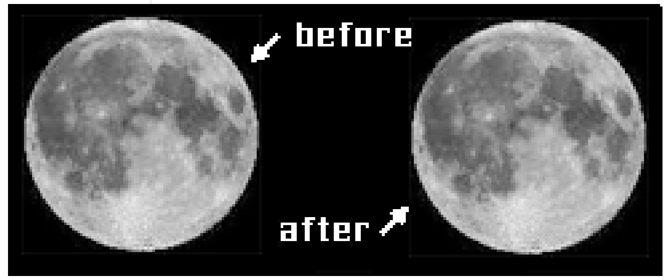


The Post-human Moon

While most peoples resist invasion, history demonstrates that successful invaders are assimilated by the very people whom they invade, and not the other way around. What will happen to the Moon as humans settle this “virgin” world? In all likelihood, the Moon will transform her settlers into her own adopted people, into Lunans, even as their activities gently alter her moonscapes from close up. This is the topic of our article, “The Moon as Virgin Territory, a World without History,” *below.*

The Outpost Trap

Technologies Needed to Break Free

Continued from MMM #198

By Peter Kokh

IV: ISRU, In Situ Resource Utilization

NASA’s announced intention is to begin a modest program of ISRU, in the form of oxygen production from the regolith. A major problem with the plan has emerged, however: NASA is designing the Lunar Ascent Module to use fuels that do not include oxygen! Yet oxygen is not only needed for life support, if transported to Low Earth Orbit, it can be used on the next run out to the Moon, saving the major expense of getting oxygen-prefuelled vehicles up from Earth into LEO. We hope that NASA is not dissuaded from going ahead with its modest and limited ISRU project, however, as it will be just the beginning, the first step in using “on location” [Latin “in situ”] resources.

First, the basics

We need to begin with basics, such as **cast basalt** and **sintered iron fines collected with a magnet**. These can provide abrasion-resistant chutes and pipes and other items for handling regolith, and low performance metal parts respectively. Then we can handle regolith more effectively to feed additional ISRU projects.

Composite Building & Manufacturing Materials

Long before we can produce iron, aluminum, magnesium, titanium and workable alloy ingredients, we can make useful building materials out of raw regolith and minimally enhanced regolith. processing elements and building materials from the regolith. Using highland regolith with a higher melting point to produce **glass fibers**, and mare regolith with a lower melting point to produce **glass matrix** material, we can produce glass-glass composites on the analogy of fiber reinforced resins (fiberglass). But to make this work we need to bring down the melting point of the mare glass matrix material further by enriching it with sodium and potassium. (A study funded by Space Studies Institute recommended the expensive import of lead as a temperature-reducing dopant!) This gives us an **action item:** *isolating sodium and potassium*, or sodium and potassium rich minerals.

If we can also isolate sulfur, we can experiment (and yes, why not here and now?) with fiberglass-reinforced **sulfur matrix** composites. Simpler yet, we can make many low-performance household items from "dishes" to planters to table tops and floor tiles from crude **raw glass** and **cast basalt**, no processing needed other than some sifting.

We will bet that glass composites, sulfur composites, cast basalt, and raw basalt glass will all find profitable terrestrial applications which may make the predevelopment of these technologies attractive to entrepreneurs, thus putting at least a close analog of technologies needed on the Moon, "on the shelf," in a reverse of the usual "spin-off" sequence. We call this "Spin-up."

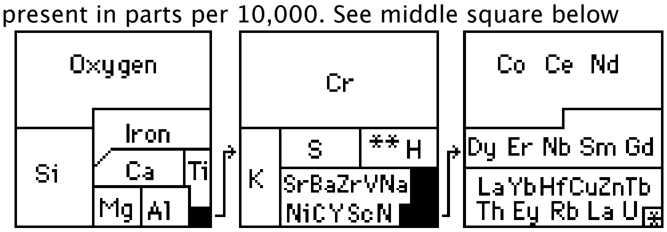
Metal Alloys

Using ilmenite (we can now map ilmenite-rich mare deposits on the moon) we can use this **iron**, **oxygen** and **titanium** mineral to produce all three elements. It is **the first ISRU Suite** to be identified. We need to identify more. Lunans will not live by oxygen alone!

Aluminum, abundant though it is, might be the hardest to produce, magnesium, somewhere in between. The catch is that for all four of these "engineering metals" the elements we regularly combine them with in order to produce workable alloys are rare on the Moon. For iron and steel we need carbon. For aluminum we need copper, and to a lesser extent zinc.

The action item here is for **metallurgists down here on Earth** to dust off old alloy experiment records. Some pathways, while doable, promised less superior results, and may have been abandoned. If they involved alloy ingredients that are economically producible on the Moon, we may have no choice but to go down that route to see where it leads. We need to do **research now** on lunar-feasible alloys that will perform in a "second-best" manner. *Second best is better than nothing.*

At a minimum, we need to be able to isolate, or produce, not only the four engineering metals, present on the Moon in parts per hundred, but all the elements present in parts per 10,000. See middle square below



Read: "Beneficiation" MMM #63, republished in MMM Classic #7, www.lunar-reclamation.org/mmm_classics

Read this NASA page also:
http://ares.jsc.nasa.gov/HumanExplore/Exploration/EXLibrary/docs/ISRU/00toc.htm

Agricultural Fertilizers

From past NASA experiments with the Apollo Moon samples, we know that regolith has about half of the nutrients needed for healthy plant growth. Using **gas scavenging equipment** on board all earth moving vehicles (road construction, shielding emplacement, material for processing and manufacturing) we can use the harvested carbon and nitrogen and hydrogen to make fertilizer supplements. Potassium we will find in KREEP-rich deposits around the Mare Imbrium rim. Other elements hard to produce on the Moon can be used to manufacture cannibalizable shipping containers and packaging materials,to "stow away" on a ride to the Moon.

Let there be color!

Combine humidity, likely to be higher in pressurized habitat spaces, with the iron fines in regolith and we get rust for a splash of color. Titanium dioxide produced from ilmenite will give us white. Combine rust and white and we get a pink. Black, many gray shades, white, rust and pink. The rest will be harder. **Metal oxide pigments will be a secondary goal** in our processing experiments.

Using the Slag and Tailings

Slag and Tailings are in themselves "beneficiated" stuffs from which we can probably make many low performance household items and construction elements. Doing so will reduce the "throughput" of our young lunar industrial complex. By treating these byproducts as resources rather than as waste ("wasources") we reuse the energy that was used to form them. This will work to greatly reduce what the settlement "throws away" - the goal being "nothing!"

Export Potential

Killing two birds with one stone has always been a desirable strategy. ISRU products from oxygen to metal alloy and non-alloy building and manufacturing materials will reduce the need for expensive imports as Lunan pioneers learn to make more of the things they need to expand their settlement and outfit it in a livable manner.

But for long-term economic survival it is essential to go beyond reducing imports. There will always be some things the settlement is no large enough, and its industries not sufficiently diversified to produce. There is a need to pay these imports. We cannot rely on any long-suffering generosity of terrestrial taxpayers. We can pay for our imports with credits from exports. Now in addition to proposed energy exports, and various zero-mass exports ranging from communications relays to broadcasting unique lunar sporting (and dance) events to licen-sing technologies developed on the Moon, there is an area of real material exports.

As long as one thinks of Earth as the Moon's only trading partner, this prospect seems outrageous. Shipping cost would make lunar products very expensive. On the contrary, it is shipping costs that will be the settlers' trump card, if there are other markets developing side by side in space. For example, while lunar building and construction materials and outfitting products may seem crude and unrefined to us on Earth, if they do the job, we can deliver them to low Earth orbit commercial space stations, orbiting industrial complexes, and orbiting tourist hotel complexes at a definite advantage over any competitive product that has to be boosted up from Earth's surface. It's not the distance, but the gravity well difference. For any product we make, as far as in space markets go, Earth will not be able to compete.

We have to think of the future economy as including not just Earth and the Moon, but other *areas in nearby space that will become areas of human activity.* This market will continue to work to the advantage of the rapidly diversifying lunar economy and growing lunar population as the population in orbit continues to grow, and as Mars begins to open up. It can only get better. But ISRU, not just of oxygen, but of many elements is the key.

ISRU and Rare Elements on the Moon

Dennis Wingo, in his recent book *Moonrush*, sees the Moon as a potential source for platinum needed for fuel cells to make the forecast Hydrogen Economy work. None of the samples returned by the six Apollo landing missions and the two Soviet Lunakhods showed this element to be present in parts per billion. Now you can say that we only sampled eight sites. Not quite true when you consider that at any given location on the Moon, only half the material is native, the other half having arrived as ejecta from impacts elsewhere on the Moon. In that sense the areas of the Moon samples are somewhat represen-tative. Wingo argues that platinum-bearing asteroids had to have bombarded the Moon. We do not quarrel with that. But it is likely that the infinitesimal smithereens are scattered all over the place with no enriched concentra-tions anywhere. Now we'd be happy to be proven wrong.

Geologist Stephen Gillett, University of Nevada-Reno, and an expert on lunar geology, now thinks that the way to beneficiate (increase the concentration of) scarce elements is to feed regolith to bacteria in vat cultures, the bacteria having been bioengineered to feed preferably on given elements.

Dr. Peter Schubert of Packer Engineering in Naperville, Illinois outside Chicago, has developed an on-paper process, patents pending, that would use shoot regolith into a 50,000 degree (C or F?) laser beam and separate out the various elements and isotopes and direct them to separate catching containers. This is, of course, the ISRU process to end all ISRU processes. We are not qualified to estimate what is involved in development of a working demonstrator, or at what scales this process would operate most efficiently. It does seem to require a considerable energy input, perhaps from solar concen-trators. It offers a glimpse of the future, when lunar settlements are shipping megatons of sorted elements for construction projects in space. (L5 revisited.)

Summing Up

- We cannot thrive on oxygen production alone! We need to concentrate on other ISRU goals, especially **ISRU Suites** or Cascades in which more than one element results.
- We need to enable with **research now**, early industries that fill needs and defray imports – Building, Construction and Manufacturing materials
- We need better, **higher resolution global lunar maps**, that show not just where we will find regolith enriched in iron, calcium, thorium, and KREEP (what we have now, at least at poor resolution.) We need orbiting instruments to indicate the richest concentrations of other elements we will surely need. Action item: suggest to NASA in detail, the kind of instruments it should fly on planned orbiters.
- As this information comes in, keep **reducing the long list of settlement locations to a short list**. What we have noted already, demands, If we truly want lunar industries and industry-based settlement, to look elsewhere than the highland-locked poles. What we need is a Highland Mare Coast, near ilmenite and KREEP deposits. That would give us access to all the major and most of the lesser abundant elements present on the Moon. But we may have to establish a number of settle-ments, each in differently endowed locations. After all, one settlement does not make a world!
- We must **research reuse options** for pre-benefici-ated tailings as building materials with lesser performance constraints. On Earth, there is no shortage of abandoned piles of tailings with which to experiment. Entrepreneurs, like artists, love free materials.
- Many experiments are possible with **obvious terres-trial applications** which may prove profitable.
- We need **an organizational machine** that will
  √ work to identify all these research needs and
  √ attract effective attention to them,
  √ serving as a catalyst to get the work done.
- The goal, if we choose to accept this mission, is to return to the Moon, ready to start building out the first resource-using settlement, so that the NASA Outpost can do science for a while, then retire to become an historic lunar national park site. In short, our goal is "Escape from the NASA Outpost" – returning to the Moon with the tools needed to avoid the "Outpost Trap." **<MMM>**

V: Industrial Diversification Enablers

1. Accepting the dayspan-nightspan energy challenge

It is not enough to develop the technologies needed to turn on location resources into products for domestic use and export. We have a little quirk in the way the Moon does its own business, rotating in and out of sunlight every lunar "day" that presents a considerable challenge. The Moon's "day" is almost 30 times as long as the one we are used to.

The challenge is to find ways to store up as much energy as we can during the 14.75 earthdaylong dayspan as potential energy, to keep us running on a lower but still productive level through the 14.75 earthdaylong nightspan.

Yes, that's why so many lunar advocates a drawn like moths to the eternal sunshine of very limited and rugged areas at the Moon's poles. But if you read the last two pages, you will know that except for water ice, the resources needed to build an industrial lunar civilization lay elsewhere. We will have to ship the ice to the settle-ments just as we ship the oil from Alaska's north coast to California.

There is no way to avoid taking on the dayspan-nightspan challenge. Turn aside from the challenge and we may be limited forever to tiny ghettos' at the lunar poles. Accept and win the challenge, and the Moon is ours, all of it.

The options for dayspan storage of energy to use during nightspan are treated in other articles. See:
MMM # 126 JUNE '99, p 3. POTENTIATION: A Strategy for Getting through the Nightspan on the Moon's Own Terms

- This article has been republished in MMM Classics #13 as a free download pdf file at both:

http://www.lunar-reclamation.org/mmm_classics

http://www.moonsociety.org/publications/mmm_classics/

2. Accepting the reduced nightspan power challenge

We might think of the pioneers waiting out the two-week long nightspan playing cards, writing their memoirs by candlelight, and making love for want of something else to do. But if we successfully meet the dayspan power storage problem, the pioneers will have enough energy to continue being productive by focusing and concentrating on less energy intensive and perhaps more manpower intensive tasks and chores, leaving manpower light and energy intensive processes for the dayspan. Inventory, scheduled maintenance, product finishing, packaging and shipping, etc.

The challenge is to take every operation and sort it into the two kinds of tasks or steps stated above. Not every industry is going to lend itself easily to an equal "division of scheduled labor." Some will need more man-hours during the dayspan and have few assignments to keep as many people busy during dayspan. Other industries may present the opposite situation. One can see arrangements where some employees work for company A during the dayspan and company B during nightspan.

Can we come to a plan whereby everything evens out and everyone is kept busy all "sunth?" (the Sun appears to revolve around the Moon once every 29.53 days, whereas the Earth does not, i.e. sunrise to sunrise marks the period we know as new moon to new moon, "month" for us, "sunth" for them. I digress. We have stated an ideal a lot of trial and error and the steadily increasing diversification of lunar industry predicts an ever-shifting employment situation. Our purpose is to suggest the process management research that we need to undertake now, industry by industry, business by busi-ness if we are to have any hope of making ourselves "at home" in the lunar dayspan-nightspan cycle. At stake is the success of lunar industrial diversification, and the competitive market cost of lunar export products.

3. Accepting the radiation challenge

"The Moon is a Harsh Mistress," blares the title of one of Robert A. Heinlein's best-known science-fiction novels. Part of that harshness comes from seasonal solar flares of great intensity. Part of it comes from incessant cosmic radiation from all quadrants of the sky. Part of it comes from the Moon plowing through space rivers of meteoritic dust left behind by comets.

All of these dangers call for shielding. The most used lunar resource of all is going to be plain regolith, piled up above habitation and working spaces, directly, or indirectly, that is over hanger-type frames with habitat structures and vehicles safely inside.

We understand the challenge, and the many options. We are prepared to meet the challenge for people in place. But what about for people in transit? A solar flare can hit the Moon with insufficient warning to allow vehicles more than a few minutes from base to return in time.

We need to give attention to the architecture and building systems to deploy at the least expense, effective wayside flare shelters at regular intervals along roadways. Whether they are lightly or heavily traveled makes a difference not in the spacing and number of shelters, but in how capacious or large such shelters are.

The Moon, like any new frontier will remain hostile and unforgiving only until we have mastered the ways of dealing with the new environment as if by second nature. The need to quite literally cover our butts from the rare but hard to predict solar flare is one we must take seriously. Lunar industry must anticipate this need.

Working out-vac in spacesuits will be cumbersome and tiring. For routine tasks such as accessing out-vac utility systems or outside storage items needed on a regular basis, it would make sense to place all these items under a shielded unpressurized hanger, shed, or canopy. Then a lightweight pressure suit will do, and that will greatly reduce stress, fatigue, and discomfort. The architectural systems for this everyday out-vac shelter system are the same as those needed in the event of solar flares. We can meet this need now by university-level architectural and engineering competitions, with ease of deployment and of shielding emplacement above the frame all being part of the challenge.

4. First industries first

It will be a challenge in itself, just to decide which industries to deploy first and just which of many possible paths lunar industrial diversification will take. As in picking a college course, one has to give attention to "prerequisite" courses. Likewise, some industries presuppose others in place beforehand, and in turn enable yet additional industries. Some industries will be viable only if developed side by side, step by step. Now there's a doctoral thesis for someone!

We make no pretense of being able to sketch such a tree of industrial ancestors and descendants, but would like to start with some notes about what we need to break out of the Outpost Trap. Rather than repeat, we ask the reader to take a second look at MMM # 91 Dec. 1995 p 4. "Start Up Industries on the Moon" - reprinted in MMM Classic #10, a free download pdf file at the sites listed above. Also MMM # 191 DEC. 2005, p 7. First Lunar Manufacturing Industries - available as a Moon Society username/password accessed directory of recent MMM pdf files; www.moonsociety.org/members/mmm/

But, first things first!

- regolith bagging and other regolith shielding systems enhanced
- prioritization of fabrication of furnishings and outfitting needs for inflatable modules
- using those same industries to fabricate things for residential quarters.
- Some early art and craft media to make ourselves feel at home with art expressed in native materials

5. One Size does not fit all

In last month's installment, MMM #198 page 4, "Modular Transportation" and following, we mentioned that importing modular factory pods and utility pods made sense. That said, a system that works on that scale, say a trailer for a Semi Tractor, may not be the best choice for a smaller installation, nor for a settlement that had grown considerably. We need to base our judgment of system efficiencies and production on scale-dependent guidelines. For a tabletop demonstration, one ISRU device may work fine, but fail utterly on a much larger scale, and vice versa.

6. Attitude is the make-or-break ingredient

If your way of operating causes a problem, you are unlikely to contribute to a solution. At every stage of human advancement, there have been shingle-qualified experts who have said this or that could not be done. A favorite trick in teaching students how to handle such situations is to ask them to jot down all the reasons such and such is impossible to achieve, and then, after they have done so, give them a second assignment: "Now right down all the reasons why we are going to do it anyway."

We have to bypass stuck-in-the present experts and luck for "Young Turks" with an open and aggressively adventurous curiosity, determined to find workarounds and new pathways where none were suspected before.

The Moon will be one hard nut to crack. I am sure a human ancestor in Africa a hundred thousand years ago, suddenly transported to the northern coast of Greenland would have thought the same thing. But we did crack that nut. The Innuit and Eskimo take living under such conditions for granted. They handle the challenges that would be life-threatening to us by second nature.

If we get raised eyebrows along the way, "industrializing the Moon, are you?" let those raised eyebrows encourage us all the more. The epic sweep of the human saga from Africa to continents beyond the shores of their home continent/world runs through our veins. We will do this, because we are humans. And as before, we will become even more human in the doing of it. For the challenge of settling the Moon will bring out new capacities in us, capacities we did not know we had, because we were never challenged before to rise to occasions such as lay before us. **<MMM>**

VI: The Entrepreneurs

1. Launch vehicles, Modules, Services

We are used to thinking of "space entrepreneurs" as involved with startup launch companies. Certainly, those are the most visible. Right now, the markets for enterprise involvement are still few, but the pace of new starts is picking up. NASA is one of the forces involved, determined to replace the Shuttle with Commercial launch companies serving the ISS with cargo and personnel transfers. The agency is also trying to find minor roles for private service providers in the return to the Moon and establishment of a small science outpost.

As the International Space Station and possible other orbital facilities grow and multiply, the market for various kinds of enterprises providing logistics services will grow with it.

2. Space Tourism

But the real glamor is in the infant space tourist industry. Here entrepreneurs are involved in providing man-rated launch vehicles, vehicle operation services (Virgin Galactic), and space destinations (Bigelow Aerospace.) This entrepreneurial area promises to grow continually, with not just orbit in mind, but non-landing loop-the-Moon excursions. Before the first of those, possibly within the next two years, some will start planning how to offer self-contained moon landing sorties.

Some dismiss tourism as a driver. This is a mistake. Discretionary income is rising, and worldwide, tourism is near the top in income-earning sectors. We have believed, that failing a viable Moon-based energy production effort, tourism alone has the capacity to open the Moon. Read MMM #161, Dec. 2002, pp. 4-5 "Tourist Clusters on the Moon." - available as a Moon Society username/password accessed directory of recent MMM pdf files; www.moonsociety.org/members/mmm/

3. Making Money by Laying Foundations

Stating way back in July, 1988, in MMM #16, we began describing a way of doing business that turns "spin-off" on its head. Instead of NASA doing an expensive crash R&D technology project at the expense of unwilling taxpayers, then, later making the technology available free to enterprises, a would-be entrepreneur looks at the technologies NASA needs (or that we need to go beyond NASA and break out of the Outpost Trap) and brainstorms them for potentially profitable terrestrial applications, creates a business plan, and goes ahead with the needed R&D to be ultimately reimbursed by willing consumers, precisely for those identified terrestrial applications. In the process, a technology needed on the frontier, or a close analog thereof, gets put "on the shelf" free of charge to taxpayers.

We have talked about a number of technologies in need of R&D, and the way to get this done in a timely fashion is not a taxpayer-paid crash program, but bu a spin-up enterprise. The options are too many to number, indeed to many to imagine.

So how do we connect potential entrepreneurs in search of a business idea/plan with our laundry list? That is the question, and in a month or two we hope to give you the start of an answer, involving a meta/mega project that will subsume and interrelate all other Moon Society projects and keep us on course on the path to a viable lunar settlement civilization. **<MMM>**

VII: Moonbase Personnel

The most critical moonbase system to success is the human one

There have been many Human Factors Research studies done at the two Mars Analog Research Stations to date, but they all suffer from involving short crew stays. Most anyone can put up with anything for two weeks. Studies aboard submarines and at Antarctic stations are more helpful, but still do not mirror conditions we will find on the Moon and Mars.

Many ordinary human activities, are not modeled because they can be postponed. This includes exercise, sport, many kinds of recreational activities, get-away-from-it-all options, indulging artistic abilities, etc.

A more thorough investigative approach should give clues as to which type of modules and facilities, and the activities that they will enable, should be added, and in what priority. At stake is general crew morale, produc-tivity, and safety as well as general health.

That said, NASA's purposes and our purposes are at loggerheads. NASA would indefinitely man a lunar outpost with crews being regularly rotated, baring events unforeseen. Our goal of breaking out of the outpost trap towards settlement, means finding ways to encourage personnel to willingly re-up, stay for "another tour" without limit, so long as health of the individual and of the crew at large is not an issue. That means providing the kind of **perks** that:

- increase morale and improve performance
- promote willingness to re-up so as to give the weight allowance for his not-needed replacement to valuable imports of materials and equipment, especially tools and equipment to fabricate and experiment

- create a plan for outpost expansion of modules, the facilities they house and activities they enable

Providing for a full range of human activities:

- getaway "change of scenery" spaces and out-places
- a range of customizing options for personal quarters
- menu diversity and variety, including fresh salad stuffs and vegetables on occasion
- schedule breaks (take advantage of the dayspan/ nightspan cycle for regular changes of pace such as a alternating types of work and recreation
- allow fraternization between crew members, without harassment, of course
- promote expression of artistic and craftsman instincts using local materials and media
- Experiment with lunar sports and other recreational activities. Lunar-unique sports and performing arts - are things that make crew begin to "feel at home".
- out-vac sport & recreation on the surface
- an indulgent spa and an exercise gym
- telecasts to Earth of everything unique and special
- "while you are here" opportunities for excursion exploration and "tourist" experienced and memories

All this both presupposes and prepares for an orderly expansion beyond the original functional and space limits of the original outpost. But that's what we need to do to "breakout of the Outpost Trap." **<MMM>**

Next issue: Part VIII: Strategies for Societies self-tasked with helping make it happen; **Conclusion** of series.

The Moon as Virgin Territory ”a world without a history”

By Peter Kokh

Apollo's leavings

Yes, "not quite," given the six Apollo landing missions of 1969-72, or if you want to be even more strict, since the first Soviet Luna probe crash landed on the farside in 1959. But the astronauts were only on scientific picnic missions. They did leave some things behind, destined to be revered objects in the first Luna City Museum some day.

But in truth, no one has ever "lived" on the Moon, not even for a short time. The Moon is largely pristine, unchanged, still waiting to be given the life that it could not give birth to on its own.

The first 4,600,000,000 (4.6 billion in U.S. usage) year period of the Moon nurturing the nascent life on Earth through its gentle tidal forces, but not sharing in the epic of life itself, is about to end. Earth Life has reached its reproductive stage, having given rise to an intelligent species capable of sowing that life in places that it could not have sprung up on its own.

Treating a virgin world with "respect"

Will humans treat this world with respect? Will they be a thoughtful caring suitor or a rapist? Many people repeat the common objection that we will only end up trashing the Moon as we have trashed the Earth.

But there is a difference, more than one, in fact. Here on Earth we enjoy life in an immense planetary **biosphere** which included the atmosphere, the hydro-sphere (oceans, lakes, rivers, and underground aquifers) the sea bottom oozes, the top soils of the continents. We do the damage we do, because up until recently, we seemed to be able to get away with it. Our ancestors might suffer, but who thinks that far ahead.

On the Moon, and Mars too for that matter, it will be different. There is no planetary biosphere. We will have to create and maintain mini-biospheres within which to reencradle ourselves. And because they will be so small in relative terms,

we will find ourselves living immediately downwind and downstream of ourselves.

Our environmental sins will hurt us immediately. We poison our mini-cradle, we die/ It's as simple as that!

Mining and Manufacturing

The Moon's surface has been "gardened" or tilled over billions of years of meteorite impacts into a top-blanket of pulverized and powdered material from 2 to 10 meters~yards deep. This smashed stone stuff is called the regolith. The composition of the regolith is the same as the upper levels of the lunar crust. In some areas, material from the mantle, below the crust, has been thrust to the surface as a rebound from major blows: the central peaks of large craters, for example.

The point is that mining operations will on the Moon will consist principally of extracting elements from this surface blanket. No ugly strip mines. No deep shaft mines. At least we do not expect a need for deep mining. Our regolith "mining" will not noticeably scar the surface, perhaps not even from fairly close viewpoints, and are most unlikely to cause any changes in the Moon's appearance from Earth, except possible albedo changes: freshly harvested regolith may cause that terrain to be a slightly darker or slightly lighter gray. At very close range one would notice the absence of any small craters in the 1-2 meters~ yards range, as our equipment rakes them smooth. Larger craters would be avoided, by passed.

All our mining an manufacturing and packaging and unpackaging operations create byproducts not immediately useful. But all these items represent some real amount of energy already spent. It makes sense to warehouse them, sorted by kind, so that when we come up with a plan to use in new ways, they are easy to find and gather. Mine tailings and processing slag might be used for low-performance building products: bricks and blocks and tiles and slabs, etc. or even cast into ceramic like household items. With a proper reuse-friendly ware-housing policy, nothing will be discarded to "trash."

Garbage

As to food and biomass wastes and other organic residues, we cannot afford to dispose of them as garbage because they are made of precious hydrogen, nitrogen, and carbon - all present on the Moon but in amounts that count as "traces" when compared with their rich abundance on Earth. All these items must be recycled into the atmosphere, "religiously".

Architectural Visual Impact

The most likely form of settlement architecture will not be the dome-enclosed city popular with science fiction artists, and so structurally impossible.(The air pressure inside, with only vacuum above, would quickly rip the dome off its foundations and blast it into the sky.) Rather, in the near term, we are looking at ever growing mazes of interconnected habitation and activity struc-tures, covered with mounds of regolith shielding. Apart from protruding antennae and heat-rejecting radiators, the view from above will be an orderly maze of mole hills.

Now while such settlements would blend into the landscape reasonably well, at least in color and texture, it need not remain so. Individuals may wish to give their own cozy homestead a special appearance. A dusting of titanium oxide or calcium oxide (lime), both easily made from mare and highland regolith respectively, would put their homestead mound in the “limelight.” One covered with iron fines exposed to steam would give a rust hue. Or one could gather moon rocks and breccia and cover the surface of their mound with them. The options are quite a few. The point is, that they all involve lunar materials and are lunar-appropriate treatments.

For more on this topic, read MMM #55, May ‘92, p.5 “Moon Roofs” - republished in MMM Classic #6, a free download pdf file from either of these locations:

www.lunar-reclamation.org/mmm_classics

www.moonsociety.org/publications/mmm_classics/

Also read MMM # 137 AUG 2000, p 5. “’Taking-back-the-surface’ Architectures” - reprinted in MMM Classic #14, pp 50-54 a free pdf download, locations above

Transportation systems

As additional outposts and settlements and remote mining operations are started, a network of lunar highways will grow to connect them into a marketing network. One of the things we can do now, or fairly soon, given much improved topographic/altitude mapping of the Moon is to determine contiguous areas within which surface transportation encounters no obstacles that need significant cuts, fills, bridging, or tunneling The next task will be to find the easiest to construct routes that link these areas without considerable detouring. Surface roads can be self-paved, i.e. graded, compacted, and sintered with microwaves to “fix” the dust and powder content. Stones and boulders can be simply plowed aside, or to the median strip, to make route identification easy.

We’ve talked about road building several times, most recently in MMM #169, October 2003, pp. 4-7, “Early Frontier Highways on the Moon” (at the end of this article is a list of related articles in previous issues #s 37, 79, 81, 82, 85, 86 - reprinted in MMM Classics #4, 8, 9.

Of course, we will have small local, and larger regional spaceports. What we won’t have is airports! It could very well be that the workhorse of long distance cargo and passenger hauling may be done by lunar railroads. This may seem anachronistic. Railroads on a world of the space age? Why not? Check out

http://www.lunar-reclamation.org/papers/rr_moon.htm

But they will blend into the moonscapes as well

We will need intermittent flare shelters along lunar highways and railroads. These shelters will be covered with regolith, so will blend in also.

Making ourselves “at home” on the Moon

Making ourselves “at home” means using building materials made from lunar materials. It means adapting our life and production schedules, our import and export schedules, and our global travel arrangements to fit in with the grain of the Moon’s natural rhythms. the long dayspans and nightspans, a sunth-based calendar. It means adapting to lunar cosmic “weather” and learning to deal with their new homeland’s harsh unforgiving aspects as if by second nature, as have all pioneers of the past. It means learning to express their artistic and crafting instincts in lunar materials. It means making do with a lunar-sourceable color pallet. It means creating new sports and new dances to take advantage of light lunar gravity while momentum stays unchanged. It means finding substitutes for familiar terrestrial products made of materials not economically producible on the Moon.

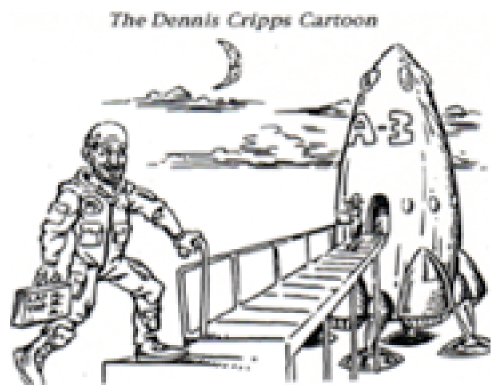
It means, in the end,
Becoming People of the Moon,
And no longer People of Earth.

The pioneers will end up belonging to the Moon, just as we belong to Earth. And that, we think, means treating the Moon with respect. In short, the Moon will change those who settle her, every bit as much as they change the Moon. It will of necessity become a symbiosis.

Lunar History to come has already begun

Our robotic probes and human crews have left the first impacts and footprints on the Moon not caused by natural processes. It is **an Overture**.

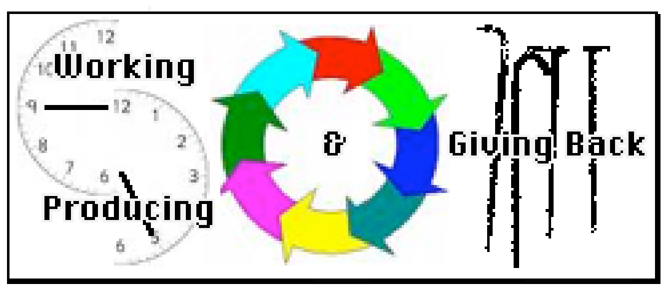
We had long ago named many features on the Moon, of course, and since Apollo, we have named many more. The pace of naming will continue exponentially, once we are there, to stay, and not just at the end of a telescope. More importantly, there will be places associated with success, with failure; places of desperation, tragedy. conflict. And yes, their will be ruins. Surface features will be put to geologically unforeseen human uses. But all this will be done together, as the Moon and humans face a future intertwined. **<MMM>**



Where the Editor had hoped to be going at this stage

MMM #200 - NOV 2006

#200 = 10 issues of MMM/year for 20 years!



“Retiring” on the Moon?

Whoa! you say. “This isn’t going to happen. We cannot afford to support people who are not producing. Well, that goes without saying. But that asserted, there may be ways, many in fact, for retired persons to make contributions that improve the gross productivity of the settlement, fully “paying their way.” If we are going to have settlements, we must find those ways. Read our article “Retirement on the Space Frontier,” *below.*

The Outpost Trap

Technologies Needed to Break Free

Continued from MMM #198 & 199

By Peter Kokh

VIII: Strategies for Organizations self-tasked with helping make it happen

Many have heeded the call

Several organizations have appeared over the years who have taken upon themselves to help advance the day when space settlement, and lunar settlement in particular, might become a reality. Space Studies Institute, the former L5 Society, the Space Frontier Foundation, Artemis Society International, The Mars Society, The Mars Foundation, The Moon Society, and the National Space Society have pursued these goals on the national and international level. NSS, however, has traditionally limited its set of tools to political, public, and media outreach.

On a smaller scale the Lunar Reclamation Society (publishers of Moon Miners' Manifesto), the Oregon L5 Society, and Calgary Space Workers have done, and still continue to do what they could to lay foundations. Other outfits have come tried for a while, only to disappear.

"Nature abhors a vacuum"

The premise on the table is that NASA, most probably with international partners, will establish a *minimal* outpost on the Moon. Several successions of the US Administration and Congress will have to go along with these plans and that makes these plans and announced intentions and commitments highly contingent and "iffy." Further, as individuals and organizations, we will have very limited ability to influence these critical decisions.

But even if all goes as planned, an international lunar outpost will fall far short of establishing a permanent civilian presence on the Moon. Permanence cannot simply be declared. It has to be earned.

Room for the rest of us to rise to the occasion

> What we can do, is t*o work to see that the needed technologies are in place to enable a "breakout"* from any such limited scope outpost, in the direction of resource-using open-ended civilian settlement.

We have looked at several general areas in which a lot of work needs to be done:

- Pushing the Teleoperations Envelope
- Shielding Emplacement Systems
- Warehousing Systems
- Modular Biological Life Support Systems
- Dayspan power storage Systems for Nightspan use
- Modular Architecture & Construction Systems
- Transportation Systems, to, and on the Moon

Tools at our disposal in seeking to further these goals

- **brainstorming workshops** – We gather those at the forefront of experimentation in a given field, ask each to list (a) what we know, and (b) what we don't know. Combining these surveys, the workshop decides on the most promising areas for collaborative research and experimentation.
- **design contests** – many things are in need of having design options fleshed out: shielding emplacement systems; shielded but unpressurized canopies and hangers; modular architectural languages; *the list is long*
- **engineering competitions** – shielding emplacement systems vie to demonstrate trouble free operation, speed, efficiency, etc.; various options for storing excess dayspan solar power for nightspan usage; interfaces between connected modules, *the list is long*
- **talent recruitment** – our collective memberships do boast some people of real expertise and talent, perhaps lost in an abundance of well-intentioned lay persons. We definitely need to recruit talented people in all areas of science and technology, architecture, systems management, biological life support, lunar agriculture, and in many more areas
- **moonbase analog stations** as equipped settings for demonstrations of candidate technologies. Various types of sites offer advantages for various types of demonstrations: lava sheet areas perhaps with handy lavatubes; any low vegetation pulverized surface area for demonstrations in which the physical attributes of lunar regolith are more relevant than the mineralogical and/or chemical ones: enclosed lighting-controlled environments where dayspan-nightspan operations can be simulated; almost any location where biological life support and food production systems can be demonstrated
- **Lunarpedia** – a dedicated lunar-relevant wikipedia which will attract quality articles about the nature of the Moon, its resources, and the possibilities for integrating the Moon into a Greater Earth-Moon economy, and the possibilities for those involved to make themselves at home.
- **Early astronomical facilities on the Moon** – we can promote design contests, engineering competitions, and the creation of university consortia in support of such a "foot in the door."
- **Citizen Exploration, aka tourism** – Loop-the-Moon tours are closer than most imagine. Beyond that, the first limited land and take off again tourist missions could conceivably occur before the deployment of the first agency outpost. Such a development will create a precedent for a truly permanent civilian presence on the Moon not limited to one station.
- **Spin-up Enterprise incubation** – draft business plans entrepreneurs could use to develop needed technologies, now, for their profitable terrestrial applications

Marching Orders for whichever organizations choose to step up to the plate

This becomes the strategy for the Moon Society, and its affiliate and partner organizations. It will come to define "who we are" and "what we do." *What we must do!*

In the near future, we hope to announce a "meta-project" that will subsume all of the above and keep everything headed towards our goals. It will have the power to become a catalyst for the needed research and development, a "research & development engine" if you will. Stay tuned. **<MMM/TMS>**

IX: A Lunar Analog Station Program can pave the way, if well-focused

by Peter Kokh, David Dunlop*, Michael Bakk**

* Moon Society Director of Project Development

** Captain of the Calgary Space Workers who are developing the prototype modular analog outpost

[Our 3rd attempt at *unzipping* the L.U.N.A. Acronym]

"Luna Underground Nucleus Analog"

"Lunar Underground" - That's us, an underground movement! Plus we *will* model **shielding**, shielding architectures and shielding emplacement options as well as monitor the thermal equilibrium benefits of an "underground" (under a regolith blanket) facility.

"Nucleus" - we are modeling not a self-contained unitary module good only for extended science picnics but the kind of *modula*r outpost that could become the nucleus of open-end expansion into a civilian, industrial settlement

"**Analog"** - we aren't trying to be exact. We need to pick our battles, getting the most bang for the buck.

We had tried twice before to come with an unzipped "Luna" acronym. Most recently, in MMM # 194 April '06 we suggested 'Lunar Underground *Network Accelerator."* In MMM #148 Sept '01, "Lunar *Utilization & Necessities Analog."* We like the new reading best.

Readings this issue and recent issues of MMM

page 10, this issue. **Analog Outpost Options Cont:** When what really matters is "*moondust behavior*", not "*moonscape appearance*" - Looking for a "physical" moonscape analog location

page 12, this issue: **More on the Calgary Space Workers Lunar Habitat Project**

MMM #195, May 2006, p 5, "**Goals of a Lunar Analog Station Program**," Kokh, Dunlop

MMM #198 SEP. 2006, p 7, "**Teleoperating Equipment on the Moon**"

Same issue, p 11. **After Utah, What/Where/How do we follow suite?**

MMM #199, Oct 2006, p 10. **Candidate Lunar Analog Sites**

Same issue, p 12. **Welcome Calgary Space Workers**

A Summary of where we are at in our planning

As stated in the MMM #195 article cited above, an analysis of research & development demonstration needs shows that the Goals of a Lunar Analog Station are quite different than those of the various Mars Analog Stations:

- We do not need to demonstrate the usefulness of human exploration of the Moon. Apollo did that well.
- We will not be demonstrating microbiological forensic techniques that might prove the Moon once had or might still have living microorganisms - we are all amply convinced by the Apollo and other evidence that the Moon is totally sterile
- Nor do we have to demonstrate geological techniques that might reveal the scope of Mars once much "wetter" past - the evidence that the Moon has always been bone dry is overwhelming.
- We don't have to model a first visiting crew exploration vehicle. NASA began that with Apollo and will continue that with the lunar outpost program

What's left for us to do?

√ NASA's plan was limited from the outset

√ It is vulnerable to budget cutbacks

NASA's plan is for a small crew outpost with limited capacities for growth and to support demonstrations of production of various elements and of lunar appropriate building materials. The agency's plans are very vulnerable to unrelated budgetary pressures, owing to the black hole of conducting an unforeseen war.

Biological Life Support Research has just been cut

Already NASA has discontinued the BioPlex project in Houston and stopped continued funding for the NSCORT program at Purdue University. Both of these programs were aimed at finding practical ways to deploy closed loop life support systems supported by plant growth and food production and waste treatment systems. There is no question in anyone's mind that a permanent presence, let alone true settlement, can be realistically supported on the Moon without coming very close to "closing the loop."

This means that it is up to efforts outside NASA to make continued progress in this area. Actually, the NASA plan was so limited from the outset, that it has always been up to us.

You can't do biological life support in an add-on closet. Life support cannot be approached as an afterthought. It has to be designed into every module and connecting corridor.

We will be studying the modular habitat prototype being designed and built in Calgary, Alberta, and to be deployed in the Drumheller, Alberta badlands, looking for opportunities to integrate biological life support functions. Biospherics must be approached in a modular fashion, so that as the pressurized interconnected habitat complex grows, the biosphere will grow with it, hand in glove, step by step. If you are designing a limited outpost with expansion as an afterthought, such an architecture will seem irrelevant, or not worth the cost.

Shielding cannot be an afterthought

Many NASA illustrations pay homage to Bob Zubrin's double tuna-can design, become so familiar to all of us as the architecture of the Arctic and Desert Mars Research Stations in Canada and Utah. The high vertical profile makes shielding difficult. Zubrin seems to dismiss radiation shielding as unnecessary. But if we are going to move beyond short tours of duty towards real permanence, we have to rely on more than Release Statements that do not hold NASA responsible for radiation damage.

Unaddressed are the major thermal equilibrium benefits of shielding. It pays to design an outpost in a "ranch style" low profile format to make deployment of regolith shielding easier. Shielding can be deployed directly as loose regolith, or as bagged or sintered regolith (blocks) for easy removal should access to the hull or a need for expansion make it necessary. We need to experiment with teleoperated shielding deployment systems, so that a landed but unoccupied outpost can be pre-shielded and ready for occupancy by the first crew. We can demonstrate a variety of such systems.

Modular Architecture, Shielding, and the Media

Granted, the Zubrin double tuna can (DTC) design has been a big hit with the press. It looks like the other-worldly mechanical "visitor" that it is. On the other hand, it does not look like "module one" of a future settlement, and that is the concept that what we want the public and the media to grasp. *We must sell modularity.* On the surface, that will be an easy task. But if we use reconditioned travel trailers and other adapted but identifiable terrestrial artifacts, that appearance may detract and distract from the lesson we are trying to get across.

However, if we shield the complex with simulated regolith, sand bags, or bags of mulch, whichever is more practical, we'll get our lesson across. A shielded modular complex will look much more serious than the DTC. The idea that we are planning *to stay* on the Moon, not just explore it and go back home, will be clear. We can make show how the shielding blanket on the Moon will perform the same services for us as does our atmosphere blanket. That we can make ourselves at home on what looks like an inhospitable world will begin to sink in. Daydreams of being stationed in a livable lunar outpost will start to look more romantic than being confined to a DTC on Mars.

Resource use should not be an afterthought

The well-advertised NASA In Situ [on location} Resource Use demonstration of oxygen production is still on the Lunar Outpost manifest. But by deciding that lunar oxygen would not be used for the lunar ascent vehicles, NASA effectively put it on the budgetary chopping block.

Lunans will not live, let alone thrive, by oxygen alone!

A lunar analog research station in basaltic terrain could get involved in cast basalt use demonstrations. Cast basalt tiles and abrasion resistant materials handling components are now being produced in several locations. If there is anything that is priority #1 it is to test regolith handling systems, and if we need cast basalt products for that, that fact would but cast basalt demonstrations ahead of everything else, perhaps even ahead of oxygen, as all other ISRU experiments will depend on regolith handling. Cast basalt products can replace many original outfitting items in the habitat module complex: flooring: table, desk, counter, cabinet tops, wall tiles, decorative items and *objets d'art.*

Other building materials to experiment with are glass-glass composites (currently just one ice-cube sized laboratory sample), steamed fiberglass cements, fiber-glass-sulfur composites, sintered regolith products, sintered iron fines products, sintered regolith products. The first goal will be to be able to demonstrate the feasibility of loca (on the Moon) outfitting of inflatable expansion modules. Demonstration of the production of pressurizable modules from simiulated lunar building and manufacturing materials would come next.

Experimentation with lunar sourceable metal alloys, as critical as it is, is best done elsewhere, because of projedct complexity and thermal conditions, and the expertise needed. In all these ISRU experiments, we must keep in mind that laboratory scale experiments, however successful, do not prove that production-scale operations are feasible. Chemical engineers will be much more help-full than chemists, for example. Laboratory scale experi-ments done elsewhere can possibly be demonstrated on a larger scale at analog facilities.

Power Production & Storage

NASA and many lunar enthusiasts are hellbent on setting up shop at the lunar south pole. To quote lunar planetary scientist Paul Spudis,

"Although polar ice is important, it is not a requirement to successfully live and work on the Moon. The poles of Moon are primarily attractive due to the near-perma-nent sunlight found in several areas. Such lighting is significant from two perspectives. First, it provides a constant source of clean power and allows humans to live on the Moon without having to survive the two-week-long lunar night experienced on the equator and at mid-latitudes. Second, because these areas are illuminated by the Sun at grazing angles of incidence, the surface never gets very hot or very cold. Sunlit areas near the poles are a benign thermal environment, with an estimated temperature of about -50° ± 10°C." –

http://ww.thespacereview.com/article/740/2

Now if you are younger than fifty, the expression "Kilroy was here," may mean nothing. This was a WW II (and perhaps older) way of "tagging" a place to say that a Yankee (an American) had been there. Now if all that you need to die happy is to know that we put up a "Kilroy was here" outpost at the Moon's south pole, than Spudis' vision will thrill you to the core.

But if by "lunar settlement" *you* mean a global presence of humanity on the Moon, then the lunar polar "gesture" (which is all it is) will be but "a tagging event."

Avoiding the Nightspan Power Problem and the Dayspan Heat Problem is *exactly what we must not do!*

As NASA has chosen not to bite this bullet, demonstrating various ways that enough excess lunar solar dayspan power can be stored to get us productively through the nightspan is a priority task for Lunar Analog Stations. That said, simulating the 14 day 18 hour long dayspan and same length nightspan will be much easier to do inside a closable structure such as a large aircraft hanger or high-ceiling warehouse than anywhere outdoors. For this kind of experimentation and demon-stration the geological and/or physical characteristics of the host terrain will be irrelevant.

Power storage options include storing waste water at a usable head height, flywheels, fuel cells, magma pools, and other devices. Yes, a nuke would do, but we think it is important to demonstrate any other non-nuclear "backup" options that would do the trick, and which would be easier to scale up or down to the power requirements of a growing lunar beachhead.

The other half of the equation is demonstration of how well various types of lunar outpost operations can be managed sequentially to take care of the bulk of energy-intensive operations during the dayspan, and the bulk of labor-intensive energy-light operations during the nightspan. Such a regular change-of-pace rhythm is bound to become a welcome mainstay of lunar culture.

Ergonomics Demonstrations

The Mars Society missed an obvious opportunity for an ergonomics layout study, by outfitting the interior of its second habitat, the Mars Desert Research Station, with essentially the same floor plans, upper and lower, as in the Arctic station which was built first. Of course, there were time and money benefits to taking a bye on the ergonomics opportunity.

The independent-minded European Mars Society will be designing the interior of the EuroMars with a clean slate. They are happily immune to the expected criticism. This unit will be just a tad taller, by just enough to squeeze in a third floor. They will be incorporating more opportunities for customization of personal quarters, euphemistically called "staterooms" as well as morale boosting perks like a spa tub, and exercise area. The objection that pioneers should feel privileged to "rough it" just doesn't cut it. High morale translates to productivity and safety, and those are far more important considerations than penny pinching economy. One must keep in mind that the Mars explorers will be away from home for two or three years, factoring in the long travel times to and fro.

A modular outpost gives much more opportunity to vary living and working arrangements and their mutual proximity or isolation. A modular outpost, particularly a "practice" one, can have its layout plan "shuffled and reshuffled" until the happiest disposition is found. A consideration, one that does not easily arise in the Mars Hab instances, is finding the best vectors for expansion of the various kinds of facilities: residential, energy generation, workshop, laboratory, fabrication shop, greenhouses, exercise and recreation facilities, and whatever other modular facilities may be needed to "break out of the otupost trap." Developing a site plan with options for expansion must be part of the site selection process.

A mix of hard body and inflatable modules will also yield valuable lessons. The option of adding new modules fabricated out of simulated lunar-processed building materials such as glass composites or fiberglass reinforced concrete is also attractive.

Lunar Analog Outposts will be innovative

It may seem to the casual observer in the public or the media that the exercises at the two operational Mars Habs are getting repetitious. Until you take a close look, all the geology experiments, the biology experiments, the GreenHab experiments, and the human factors studies seem to produce nothing new. Take it from one who has been on two MDRS crews: that is definitely *not* the case. New things are being learned crew after crew, and I remain a staunch supporter of the Mars Analog program. But the illusion or repetition dogs the program.

Next year, there will be a 4-month long exercise by one crew at the Arctic outpost on Devon Island. That will definitely test the reliability of utility systems, at a location that is logistically quite isolated, as well as be a superlative opportunity for human factors studies. Now if the Mars Society would embrace the projects to the Mars Home Foundation which wished to build a demonstrator Martian Village out of materials available on Mars, that would be really helpful.

In contrast, the Lunar Analog Station programs will have no shortage of new things to do and try and test. The clear sign of progress will work to keep the media, and the public interested, as well as to educate them on the possibilities of human settlers making themselves permanently at home on the Moon.

Lunar Analog Outposts and Tourism

When the Moon Society was founded in July 2000, the flagship project announced to celebrate the society's birth was Project LETO [Lunar Exploration & Tourist Organization] conceived of as both a tourist facility and as a research station. On first glance, this would seem to be a marriage made in heaven. But having four weeks of experience at MDRS in Utah, I'm convinced that research is best done without the visual or actual interference of curious onlookers. Now in the 2005-2006 field season we experimented with first one web cam then as with as many as six. This works well, and does not disturb research activities.

What does seem most important, even to the point of being sacred, is to preserve the illusion that you are on Mars (or, in our case, on the Moon) as the illusion helps one take the experimentation and/or exercise seriously enough to ensure superior results. In short, it does not disturb research if visitors or tourists can watch *so long as they are out of sight of the researchers.*

One way to keep the required separation is the use of web-cams. What about an analog of a duck-blind? That might work for outdoor activities, but without a great number of such blinds, we couldn't ensure visitors that there would be anything worth observing on a regular basis. Web cams or remote TV cameras would seem to be the better answer. Actual supervised "do not touch anything period!" tours could be conducted when the facility was not occupied.

At MDRS, media visits are allowed, but scheduled by program headquarters to minimize interference with MDRS activities. Nonetheless, interfere they do.

Visitor access is important. We will have our faithful followers and enthusiasts who will want the high of seeing this glimpse of the future for themselves. What we can't do is make the analog outpost a zoo exhibit! or create conditions where the crews feel that they are zoo animals. But growing our constituency is of primary importance as well. So how we can best satisfy the needs of both the various crews and the faithful/curious without shortchanging either is an area that deserves much fore-thought and should be part of the original site plan.

The commercial connection

Whenever or wherever the brand or supplier of any needed equipment is not crucial, the opportunity to have the equipment donated "by the official refrigeration supplier to the Moon Society Lunar Analog Outpost" etc. (for sake of example) should not be passed over lightly. We will always have less money than we need. And when performance or specifications are crucial, all the more reason, for advertising punch to approach a manufacturer or distributor for product donation or free lease.

We have talked many times about the "spin-up" paradigm, much more powerful than the "spin-off" system in place for decades. In spin-up, an entrepreneur develops a technology or product which happens to be needed on the frontier, precisely for the potential "here and now profits" from any terrestrial applications. As we succeed in encouraging entrepreneurs to take this route, they can test and showcase their products at an analog moonbase location, as an effective advertising ploy. The donation of a model, when it can be integrated into the analog moonbase operations, would be a big plus.

We may be the small guys in town, but we have the bigger dreams, the more powerful dreams, the only dreams that make sense in the long run. There may be several analog lunar station operations. Between us, we can leverage our way to reality. **<MMM>**

RETIREMENT on Space Frontiers

by Peter Kokh, *uniquely qualified to write on this topic!*

A revolution in the way individuals now "do space"

"Retire" on the space frontier? It is a jolting idea considering that no one anticipates the drastic change in the regime of short tours of duty that has been taken for granted since Yuri Gagarin became the first human in space more than 45 years ago.

In last month's issue, "The Outpost Trap, Part VII: Moonbase Personnel," on p. 7, we spoke of the first crack in this regime, the option of "re-upping" or signing up for a voluntary tour of duty extension. We also talked about the need to give serious constructive attention to the matter of crew perks, particularly those which could foster a growing sense of being truly "at home" in one's off-Earth situation. These developments will slowly usher in the revolutionary paradigm shift from simple "staffing" to genuine life-choice "settlement." We see it as a natural and gradual evolution, not as a sudden revolution.

But what do we do with those who reach the traditional age of retirement? Of course, if they still have what it takes to continue being productive in the duties of their current job, they could continue to work. That just postpones our question.

We need everyone to produce, to contribute

The situation will be quite different from that in most societies on Earth. On the space frontier, we will not be in a position to so easily afford the luxury of "carrying" those who stop (or never start) producing. The answer, of course, is to find productive ways for retired persons to continue to contribute at a slower, more relaxed pace, if need be, or simply by shifting gears and focus to another area of productivity and contribution.

We need to see "retirement" as a shift in gears, in pace, and in the many ways of being productively busy. This continues the changes we now see as the WW II Baby Boomers come of retirement age. Actually, ever more people of "retirement age" have been choosing a shifting of gears to productive hobbies over "the rocking chair in front of the TV." These days, retirement need not mean being without a schedule. It can mean a change from being scheduled by others to "scheduling oneself."

In fact, on the frontier, there will be many things deserving attention, for which we will not be able to spare persons in their "most productive years." Until we have retirees to take on such roles, many of those things will just have to remain unaddressed.

Keep in mind, that a development parallel to allowing personnel to stay on duty up to retirement age could well be allowing personnel to enter into stable relationships and have children. But that's a sequel article!" Here, then, is the start of a list of such helpful retirement activities:

√ **Management assistance:** some management tasks cannot effectively be delegated off-world, but need to be done by those directly involved. But retired persons could assist, freeing others for production tasks.

√ **General Deskwork:** taking over some of the desk work functions up to then teleconducted by less expensive support personnel on Earth. There will also be office work that cannot be done "efficiently" from a remote location.

√ **Parenting Relief:** retired persons could relieve new mothers by providing childcare so that the mothers can continue working

√ **Part time relieving:** as an alternative, retired persons could relieve others in their field of experience, for childrearing sabbaticals.

√ **Teaching, Tutoring and Mentoring:** much of education can be done remotely, by canned or live video. But retired persons could be on hand to give individual attention and assistance tot young students.

Nothing keeps a society more cultural intact than vigorous and widespread intergenerational contact. With grown children frequently moving away from the hometown root-source for employment, the super-family chain is all too frequently broken. Skip-generation teaching and passing on of values could be the preventative of choice.

Included in this paradigm might be assignment of recycling chores to the young, and helping them appreciate the responsibility which all pioneers must share of maintaining their fragile minibiosphere.

√ **Continuing Education:** in this area as well, much can be accomplished by canned or live video or internet instruction. But having a qualified real person for occasional or regular tutoring can be essential.

√ **Art, Craft, Music, Dance Instruction:** Whether for young people or working people in their after hours and weekend spare-time, this service would be of much value. The place of culture and the arts in any society is far from trivial. But we won't be able to spare "working people" to foster this activity.

√ **Historian:** retired people could compile oral histories of the early pioneers, and do other similar tasks to ensure that the lore of the pioneers is preserved for future generations of Lunans.

√ **Writers, Playwrights, Choreographers:** Retired people who have had little time in their working years to devote to literature and the arts, will have more time to dedicate to creating works for all to enjoy.

√ **Gardening, Harvest Processing, Cooking, Cuisine Development:** Hopefully, once, thanks to made-on-Luna building materials and habitat modules, we can afford to provide housing with real elbow room, home garden space will be provided as a matter of course. But main-taining a garden may be easier for retired persons than those working full time. They may also have more time to experiment in the development of new recipes and whole cuisines based on what had been and is being grown in lunan gardens and farms.

√ **Care and Visiting for the injured and ill:** No one would suggest that retired persons play doctor, but they could certainly train to be nurses, orderlies, or simply volunteer visiting care providers.

Summary: a lot of things for which the early pioneers cannot spare anyone of "working age" to take care of, but which are nonetheless sorely needed in a frontier society, can be addressed, at least in part, by "retired persons". Whether the government or the direct beneficiaries take care of adding to their retirement incomes, is a question left to the pioneer societies to address **<MMM>**

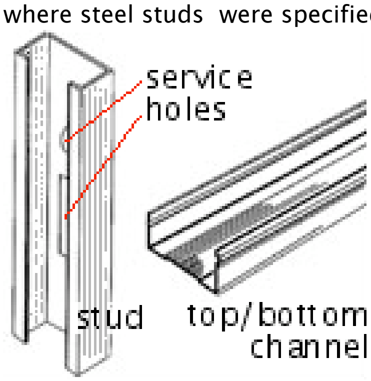
Drywall aka Sheetrock® for the Moon

by Peter Kokh, with Dave Dietzler

Perhaps many of our readers will have had some experience hanging and mudding Sheetrock®, or as they call it in Wisconsin, at least, "drywall." While there are indeed some who do this for a living and are quite proficient at it, in general, it is not rocket science, and many more "home warriers" with some "fixer upper" experience are familiar with this way of cladding home interior walls.

Manufacturing airtight pressurizable habitat modules on the Moon will not be a task for amateurs. That is one area where life quite literally depends on high quality performance, after all. But interior wall construction and finishing can perhaps safely be left to homeowners or part-time (afterhours) handymen.

So what will they have to work with? Well, a quick trip to the local Lunar City *The Home Depot* or *Lowes* will show that there is no lumber. No 2x4s? Well, not wood ones. However, some of us, myself included, may have had experience putting up commercial interior walls where steel studs were specified by code.



Steel? We are not talking girders or I-beams here. Steel studs are very thin lightweight somewhat flexible channels, with side slots at intervals for runs of romex or other utilities. You attach the sheet of drywall or sheetrock to the steel studs with special screws. Any and all flexibility and seeming flimsiness disappears once the sheetrock is affixed, holding the assembled section rigid and steady.

Now we should be able to produce some sort of alloy construction studs on the Moon. But what about drywall or sheetrock?

> Drywall {Wikipedia] "is made primarily from **gypsum plaster**, **semi-hydrous** form of **calcium sulphate** (CaSO4.1⁄2 H2O). The plaster is mixed with fiber (typically paper and/or **fiberglass**), **foaming agent**, various additives that increase mildew and fire resistance, and water and is then formed by sandwiching a core of wet gypsum between two sheets of heavy paper or fiberglass mats. When the core sets and is dried, the sandwich becomes rigid and strong enough for use as a building material." (bold blue words are links to separate Wikipedia entries.)

By serendipity, a tool of the trade for frequent MMM contributor, Dave Dietzler of Moon Society St. Louis, he was watching a Public Television episode of Bob Villa's "Home Again" in which a fiberglass sheathed drywall was used instead of the usual paper-gypsum-paper sandwich.

www.bobvila.com/BVTV/HomeAgain/Episode-1514.html

In this episode, the team "installs 5/8-inch fiberglass drywall. Replacing the paper-faced drywall with fiberglass on both sides will protect the walls from invasive mold and fungus. Installer Chris McEvoy shows how to handle drywall installation with metal studs ..."

This may be new to most of us, but with all the problems with mold caused by Hurricane Katrina in New Orleans, there is already a big push for fiberglass-faced gypsum board as an improved replacement for the familiar paper sandwich board.

Dave writes: "Instead of plaster on paper, this was made with tightly woven glass fiber cloth. We can make plaster, gypsum, anhydrite, whatever; it's all calcium sulfate mixed with some water and allowed to harden on the Moon by leaching regolith with sulfuric acid as I have described in a previous MMM article [# 159 OCT. 2002, p 5. "Lunar Cement` & Plaster", D. Dietzler] and at www.moonminer.com. Does the glass weave bind to the plaster when they make the drywall or is it bound with a resin? I don't know. If a resin is needed we either use sodium silicate which might not last or good old glass-glass composite. Thus we can make drywall without paper. And it will not be affected by mold or fungus. Now, what if we make 2x4s out of AAC [autoclaved aerated concrete - www.aacpa.org] and hold them together with screws and attach the drywall with screws? We can make interior walls with conventional carpentry techniques. I don't know about nailing things. That could crack the glass-glass cloth on the drywall and I don't know it the AAC studs would take nails either. Screws are better anyway. They hold better and can be removed easily if we want to remodel interiors."

In an answer to Dave's questions, I should think that the fiberglass matt would bond naturally to the wet gypsum which would impregnate the mesh, allowing a skim coat surface. The 8"x8"x24" sample of AAC I have will take both screws and spikes, as well as sawing and drilling. But I question how well AAC "studs" will "hold" them, as AAC has no grain, but instead is a fine granular material. I would prefer lighterweight steel or aluminum studs as I have experience with them.

Prior to hearing about fiberglass faced gypsum board, first from Dave, and then on the News in connection with the mess in New Orleans, I had thought of using Durock® in stead of drywall. Durock® is fiberglass-faced cementboard, commonly used as a base for ceramic tiles in wet locations such as kitchens and bathrooms. I have had experience with that product also. Indeed, producing such a steel stud Durock®-faced lime whitewashed *wall section* as an exhibit for ISDC 1998 as part of the Lunar Homestead Exhibit, was one of the many things that did not get done, simply because time ran out.

It is good to have two options or more, as one may be easier to produce in the early settlement when industrial diversification has not far progressed. As to stuffing such a stud wall, either for thermal insulation or for acoustic deadening, we have choices also: fiberglass batts can be made on the Moon, and AAC slabs could be tucked inside also. But AAC's use is limited where impact resistance is important. An AAC slab or door could be broken in half by a good blow. **<MMM>**

Related Readings:

- MMM # 65 May 1993 p 6. MOONWOOD: Fiberglass-Sulfur Composites, republished in MMM Classics #7
- MMM # 76 June 1994, p 4. INSIDE Mare Manor; Interior WALLS - republished in MMM Classics #8

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Milwaukee, WI 53208

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302 Washington Street #711
San Diego, CA 92103

If you are a member of a National Space Society chapter other than those listed above,
ask a chapter officer to contact
The Lunar Reclamation Society (NSS-Milwaukee)

About *special chapter group subscription rates*

Peter Kokh, Editor President
kokhmmm@aol.com
1-888-266-2385

Bob Bialecki, Treasurer
bobriverwest@yahoo.com
1-414-372-9613

~~Do not~~ make checks payable to
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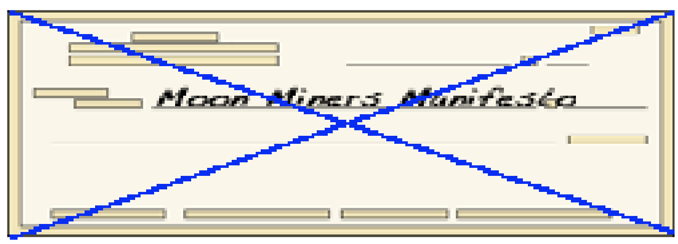

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The Moon Society accepts Credit Card payments.
The Lunar Reclamation Society does not.

As to other chapters,
Please contact them directly about
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